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NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

PRIVATE TELECOMMUNICATIONS SYSTEMS:
A SYSTEMS APPROACH

by

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September, 1990

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Unclassified

SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

1a REPORT SECURITY CLASSIFICATION Unclassified	1b RESTRICTIVE MARKINGS
2a SECURITY CLASSIFICATION AUTHORITY	3 DISTRIBUTION/AVAILABILITY OF REPORT Approved for public release; distribution is unlimited.
2b DECLASSIFICATION/DOWNGRADING SCHEDULE	
4 PERFORMING ORGANIZATION REPORT NUMBER(S)	5 MONITORING ORGANIZATION REPORT NUMBER(S)
6a NAME OF PERFORMING ORGANIZATION Naval Postgraduate School 6b OFFICE SYMBOL (*If applicable*) 54	7a NAME OF MONITORING ORGANIZATION Naval Postgraduate School
6c ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943-5000	7b ADDRESS (*City, State, and ZIP Code*) Monterey, CA 93943-5000
8a NAME OF FUNDING/SPONSORING ORGANIZATION 8b OFFICE SYMBOL (*If applicable*)	9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c ADDRESS (*City, State, and ZIP Code*)	10 SOURCE OF FUNDING NUMBERS Program Element No. / Project No. / Task No. / Work Unit Accession Number

11 TITLE (*Include Security Classification*)
PRIVATE TELECOMMUNICATIONS SYSTEMS: A SYSTEMS APPROACH (Unclassified)

12 PERSONAL AUTHOR(S) Panagiotis George Pangalos

13a TYPE OF REPORT	13b TIME COVERED	14 DATE OF REPORT (*year, month, day*)	15 PAGE COUNT
Master's Thesis	From To	September 1990	113

16 SUPPLEMENTARY NOTATION
The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

17 COSATI CODES			18 SUBJECT TERMS (*continue on reverse if necessary and identify by block number*)
FIELD	GROUP	SUBGROUP	Private telecommunications systems, Computerized Private Branch Exchanges (CPBXs), Request Of Proposals (RFP), life cycle costing (LCC).

19 ABSTRACT (*continue on reverse if necessary and identify by block number*)

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The process of planning private telecommunications systems is discussed in detail with an emphasis placed on the comparative evaluation of computerized branch exchange (CPBX) and local area networks (LAN). This study shows that a computerized private branch exchange is preferable to a local area network in a medium-sized organization in general.

20 DISTRIBUTION/AVAILABILITY OF ABSTRACT	21 ABSTRACT SECURITY CLASSIFICATION	
☒ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT ☐ DTIC USERS	Unclassified	
22a NAME OF RESPONSIBLE INDIVIDUAL Myung Suh	22b TELEPHONE (*Include Area code*) (408) 646-2637	22c OFFICE SYMBOL AS/Su

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted. All other editions are obsolete.

SECURITY CLASSIFICATION OF THIS PAGE

Approved for public release; distribution is unlimited.

Private Telecommunications Systems:
A Systems Approach

by

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Submitted in partial fulfillment
of the requirements for the degree of

MASTER OF SCIENCE IN TELECOMMUNICATIONS SYSTEMS MANAGEMENT

from the

NAVAL POSTGRADUATE SCHOOL
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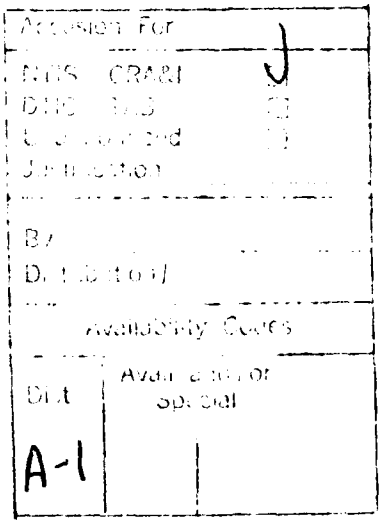
ABSTRACT

This study examines the importance of *private telecommunication systems* for voice and data communication. It demonstrates an orderly process through which a medium-sized organization can transform a complex telecommunication environment into a progressive and self-reliant telecommunication utility.

The process of planning private telecommunications systems is discussed in detail with an emphasis placed on the comparative evaluation of *computerized branch exchanges* (CPBX) and *local area networks* (LAN). This study shows that a computerized private branch exchange is preferable to a local area network in a medium-sized organization in general.



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I. INTRODUCTION

A. BACKGROUND AND CONCEPT

In recent years, telecommunication systems have played a critical role in political, economic, social, and military life. The services that can be offered for the transmission of voice, text, data, and image have reached a level which was inconceivable a few years ago. The basis of these services is the existing Public Switched Telephone Network (PSTN) which covers the entire world and was originally designed and implemented to service voice communications.

The rapid and continuing advance in electronics over the last 20 years, together with the considerable growth of computers and other intelligent data equipment, has increased the demand for more efficient and flexible data communication networks. This increased demand can be met either by expanding the capabilities of the existing Public Switched Telephone Network (PSTN) or by establishing a private network which will be tailored for the users' needs.

The PSTN is gradually being converted from an analog network to a digital network, but a great deal of older analog equipment is still in use. The huge capital costs involved make the conversion a slow process, particularly because most equipment still works very well. Anyway, voice and data are supported extremely well at the rates most in demand, and full interconnectivity, interoperability, and uniformity are the major advantages that can be offered.

Major disadvantage of PSTN include the very poor services in (1) mixed voice and data, (2) asynchronous data and (3) data rates higher than 56 Kbps.

Also there are times when services are blocked either because of outage or extraordinarily heavy usage. Finally, there are many situations in which the telephone network can not serve the requirements of specific geographical locations.

For the disadvantages already mentioned and some recent important changes in the ownership, control, and marketing of telecommunications services, there has been a constant rise in the number of private networks in the last few years.

A private telecommunication system is used to connect voice, data, text, or image terminals of an organization, an office building, a factory, a military base, or a local area without relying on the Public Switched Telephone Network. Such a system can be dedicated to a specific group of users and is not available to the general public.

A private telecommunication system is considered as more flexible and efficient than PSTN due to its ability to support mixed voice and data, asynchronous data, and various nonstandard data rates. However, the lack of full interconnectivity and the difficulty of integrating data channels with channels of the PSTN are factors dictating that these two networks have to be considered together, for their mutual advantages.

This thesis proposes a conceptual model for a private telecommunication network, interfaced with the existing Public Switched Telephone Network, and is based on actual specifications and requirements.

B. OBJECTIVES

A reliable and well organized telecommunication system is essential for the success, efficiency and productivity of any kind of organization. This thesis is intended to provide medium-sized organizations with guidelines and recommendations to integrate its obsolete communication system.

Two main issues have to be considered during the integration process: the new network has to meet the organization's functional needs, and it has to fit into the existing environment. These issues are closely related and depend upon the major features needed and the technical and the cost justification of the system.

Certain factors, such as connectivity, speed, capacity, cabling, security, multivendor support, and economy, are very important for the optimal choice among the candidates of private networks, Private Branch Exchanges (PABXs), Local Area Networks (LANs), Central Exchanges (Centrexes), etc.

This thesis will go through the following steps:

- Analysis of the existing telecommunication system.
- Definition of new telecommunication requirements.
- Volume of required telecommunications. Analysis of present traffic volume and expected volume growth.
- Definition of original objectives with the new volume requirements.
- Survey of techniques of transmission, reception, and signal processing to determine if existing techniques are adequate.
- Examination of the different kinds of Private Communication Networks that meet the new needs.

- Survey of current available vendors' systems.
- Life cycle cost analysis.
- Selection of two or three vendors' systems for final evaluation.

C. SCOPE AND ORGANIZATION

This research focuses on the importance of private communication networks in conjunction with the existing Public Switched Telephone Network (PSTN), for voice and data services. It also demonstrates the process through which an organization can tackle a complex telecommunication environment with a progressive and more self-reliant telecommunication utility.

Private networks concerning wide or metropolitan geographic areas, i.e., WAN or MAN, are not examined, as the main concern is a small local area. Also, capabilities for image processing and teleconferencing are not addressed.

Background information, which should help to illuminate the discussions in the following chapters are presented in Chapter II. Chapter III describes the main private telecommunication systems, while in Chapters IV and V an approach for technical and economic evaluation is presented. The conclusions are presented in Chapter VI.

II. TELECOMMUNICATIONS FUNDAMENTALS

A. OVERVIEW

Communication is the exchange of information or the passing of messages from one point to another. *Information* is the interpretation of data, and *data* is the representation of text, numbers, instructions, etc., in a form that they can be stored, manipulated, and transmitted by devices. *Messages* are a sequence of characters used to convey information or data.

When the distance between two points wishing to communicate is quite long, the compound word *telecommunication* is used, where the word "tele" in ancient Greek means "far". There are many ways of communicating over long distances, such as using light or smoke signals, electrical signals, drums, etc. In this document the term telecommunication deals with the service of providing only electrical communication at a distance.

A telecommunication system in its basic form consists of an information source (*transmitter*), an information sink (*receiver*), and a transmission medium (*channel*) for moving the information between the source and the sink. The *transmitter* converts the information from an input device into an electrical signal. The *receiver* reconverts the received signal to its original form and sends it to an output device. The signal from the transmitter is transmitted over *channel*, which can be represented as a network or a series of networks.

A network in telecommunications is defined as a means of connecting devices so that any user in the network can communicate with any other user. Networks have evolved in various directions with respect to the principal requirements of provided services, the geographic span, the way that the nodes are interconnected, etc.

Today, the largest and most important telecommunication system is the Public Switched Telephone Network (PSTN) involving a large number of devices, cable or radio channels, mechanical and electronic switches, and control stations. Since the primary task of this system was to provide a simultaneous two way transmission of analog data (voice), economies of scale dictated that digital data should be converted to an appropriate form to be transmitted through the PSTN.

New system architectures and theories are being employed for digital data transmission and the separation of telecommunications to two distinct disciplines, transmission and switching, tends to disappear.

This chapter is intended to provide minimum background information for the following chapters, by discussing briefly some basic concepts of network classifications, the Public Switched Telephone Network (PSTN), and the transmission and signaling of information in conventional and digital telephony.

B. CLASSIFICATION OF TELECOMMUNICATION NETWORKS

A network that supports telecommunications involves the emission, transmission, or reception of voice or non-voice information over a channel of some type, such as wires, radio, microwave, or other electromagnetic means.

Basically, a network consists of a number of *nodes* connected together by communication *links* or *circuits*.

Nodes are *switching centers* or *stations* that can support thousands of users. Links are physical circuits between two points. Links connecting users to network nodes are called *user links* or *local loops*, and links connecting network nodes are called *trunks* or *junctions*. In a common user system, the circuits between users and nodes are referred to as the *local access network*, and the circuits between the nodes are regarded as the *main network*.

There are many ways in which a telecommunication network can be classified. Some basic classifications are described bellow.

1. Technology.

According to the technology that a network employs, networks may be classified in three categories: *switched*, *private*, and *broadcast* communication networks:

a. Switched communication networks

These are a collection of interconnected nodes where communication is provided by routing information through the network nodes. A further classification of these kind of networks follows:

(1) Circuit Switched Networks

They provide dedicated connection between nodes for the duration of a call. Once a call is placed, a dedicated physical path is set up and the information travels over a connected sequence of links between the two connected nodes. A node in

such a system may be an electromechanical or an electronic switching device. The telephone network is a circuit switched network.

(2) Message Switched Networks

Information in the form of messages is transmitted in both directions between nodes. At each node the entire message is received, stored briefly, and then transmitted as soon as the next node becomes available. It is not required to establish a dedicated physical path between two nodes. The nodes in this system are usually minicomputers. The telegraph system is a message switched network.

(3) Packet Switched Networks

A special case of message-switching is packet-switching. Packet-Switched networks are more efficient and faster than message-switched networks. Information is transmitted in the form of small data packets, stored briefly in the main memory of computer switches, and then passed on to the next available node. Most large modern data networks are now packet switched networks.

b. Networks of Dedicated Lines

These provide a permanent, dedicated path between communicating parties.

c. Broadcast Communication Networks

Broadcast networks involve one or more nodes that broadcast information to a large number of users by employing radio, television, or satellite systems.

2. Topology.

This classification of networks is concerned with the ways that two or more nodes are interconnected via communication links. Some of the most important and widely accepted topologies are shown in Figure 1 and briefly discussed below:

a. Star topology

A group of switching offices connected directly to an arbitrate selected switching office, called tandem exchange. (Figure 1a).

b. Mesh topology

A connection where each switching office is connected by trunks to all other switching office. (Figure 1b)

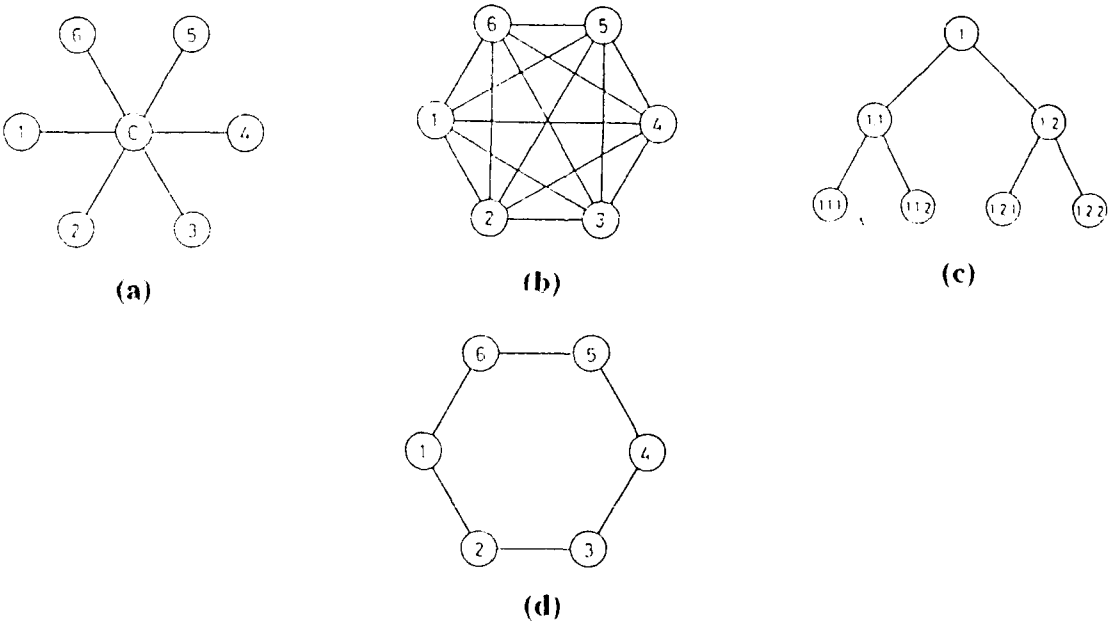

Figure 1: Network topologies [Ref. 1: p.78,79]

c. Tree topology

A connection where all nodes of the network are connected together by links but no loops are contained. (Figure 1c).

d. Ring topology

A connection where each node is connected with two links and the connection is a closed loop. (Figure 1d).

3. Geographic span.

According to the number of users and the distances between them, networks are classified as follows:

a. Local Area Networks (LAN)

Networks that are typically used to connect all kinds of different terminal devices together providing a high speed operation (Mbps), low error rates, and high reliability. They are narrowly owned, usually complete ownership by a single organization, and the distance between the devices is few miles or less. Finally, these networks use two techniques to carry messages from one device to another: *baseband* and *broadband*.

Baseband is the technique where only one signal can utilize the transmission medium at a single instant, while broadband allows several signals to occupy the same transmission medium simultaneously.

b. Metropolitan Area Networks (MAN)

Networks that cover an area of high population and mainly short distances between the users, such as a city. There are analog and digital Metropolitan Area Networks. Analog networks use mainly broadband coaxial cable as transmission medium, such as the cable television. Digital networks connect computers, and LAN techniques are used. Finally, a subnetwork is provided for the area's internal connections.

c. Wide Area Networks (WAN)

Networks that cover large segments, such as cities or the entire country, and the distances between the users are long. The main purpose of these networks is to interconnect many smaller LANs with limited switching capabilities. Regardless of its technical suitability, most WANs use the existing PSTN and are limited by the low bandwidth cable. The error rate is higher than that of LANs, so reliability is low.

C. THE PUBLIC SWITCHED TELEPHONE NETWORK (PSTN)

The Public Telephone Network is the largest *circuit-switched* telecommunication network. As a telecommunication network, a basic conventional telephone network consists of a *transmitter*, a *receiver*, and a *communication medium*. The transmitter is the mouthpiece of a telephone handset, which converts the sound into electrical signals. The receiver is the earpiece of the telephone handset, which reproduces the original sound from the received electrical signal. Finally, a pair of wires is used as the communication medium between transmitter and receiver.

Actually, the Public Switched Telephone Network is more complicated, involving many separate elements and subsystems working together in order to accomplish the operational requirements. There are *terminals* or *stations* to act as an interface between users and the system. There are *cables* or *local loops* that connect the terminals to a local switching office. There are *switching offices* or *nodes* that enable any terminal to be connected to almost every other terminal. Finally, there are *links* or *trunk circuits* that interconnect the switching offices. The elements of the PSTN are shown in Figure 2.

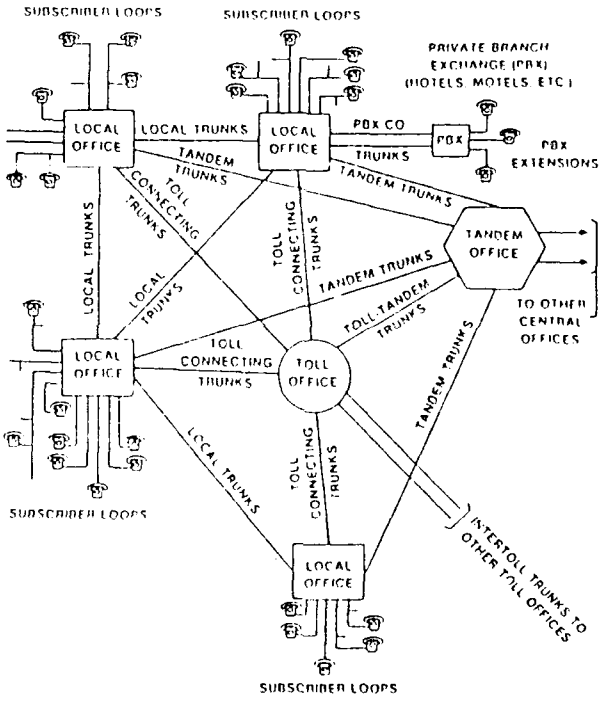

Figure 2: The Public Switched Telephone Network [Ref. 2: p.70]

These elements may be categorized into the following three main categories. The first two are discussed briefly in this chapter and the third one is discussed in Chapter III:

- Terminals.
- Transmission facilities.
- Switching facilities.

D. TERMINALS

Today,the existing terminals that can be connected to the PSTN may be classified into three broad categories: voice, message, and data terminals.

1. Voice terminals.

There are a variety of voice terminals depending on the kind of information that is required to be transmitted, whether analog or digital, and the specific functions required to be carried out. The most common voice terminals are: standard telephones, electronic phones, digital phones, and special phones.

a. Standard telephone

The basic voice terminal (rotary or push button) using analog transmission techniques to transmit voice over a twisted pair.

b. Electronic phones

Another kind of analog telephone which uses a microprocessor providing more functions and flexibility. These instruments also provide data transmission by adding a special interface card to the phone.

c. Digital phones

Similar to the electronic phone, they digitize the voice without using an interface card. Thus, these instruments use digital transmission techniques to transmit data or digitized voice over the same twisted pair.

d. Special phones

Voice terminals provided by several manufacturers of Private Branch Exchanges (PBXs) in order to carry out specific functions.

2. Message terminals.

Message terminals provide written communication. Written or printed documents, such as text, graphics, and messages, are converted before being transmitted to tones in the voice frequency range. Today, the most common message terminals in use are the telex, the facsimile, and word processing together with electronic-mail.

a. Telex

A teleprinter using a conventional keyboard, transmitting 66 words per minute (50 bits per second). Messages typed at the transmitting terminal can be received in print form on the receiving terminal.

b. Facsimile

A device which transmits hand written or typed documents, photographs, and drawings. The analog facsimile requires about six minutes to transmit a single page, while digital devices require less than a minute.

c. Word processing and Electronic Mail

The most recent message type service. Text can be stored, recalled, printed, and sent or received almost immediately by electronic mail. As with facsimile terminals, connections between word processing terminals can be set up over the telephone network.

3. Data terminals.

These terminals are, of course, digital. They exist in the form of minicomputers, microcomputers, main frames, printers, and other computer peripheral devices. Data terminals essentially convert digital data into electrical signals which can then be transmitted over the PSTN.

E. TRANSMISSION FACILITIES

Transmission deals with the conveyance of any kind of information, from one point to any other point of a network, by means of signals. The most significant transmission related concepts are the nature of information, the transmission media used to propagate the signals, the modulation techniques employed for encoding data prior to transmission, and the multiplexing techniques employed for preserving the data boundaries.

1. Nature of information.

Information of any type, analog or digital, can be transmitted in two ways: analog or digital form.

a. Analog transmission

Concerned with the transmission of *analog* or *digital data* in the form of *analog signals* over a suitable transmission media.

Analog data, such as voice and light, are continuously variable on some interval. *Digital data*, such as text and numbers, are coded in discrete separate pulses.

In order to transmit analog or digital data over an analog network, they have to be converted to electromagnetic signals. Such signals varying continuously between a maximum and a minimum value, and are called *analog signals*. (Figure 3a).

The choice of the transmission media depends on the range of frequencies that the transmitted signals contain, and the most common used media are wire pairs, coaxial cables, optical fiber cables, atmosphere, and space propagation.

Generally, an analog transmission system is used to transmit analog signals, however, it can also be used for transmission of digital data, using a specific device called *modem* (modulator/ demodulator). The modulator is included for transmission and the demodulator for reception.

Finally, in order to achieve longer distances of transmission, *amplifiers* are used to boost the energy in the signals.

b. Digital transmission

Concerned with transmission of analog or *digital data* in the form of *digital signals*, over any medium. A *digital signal* is a discrete or discontinuous signal. (Figure 3b).

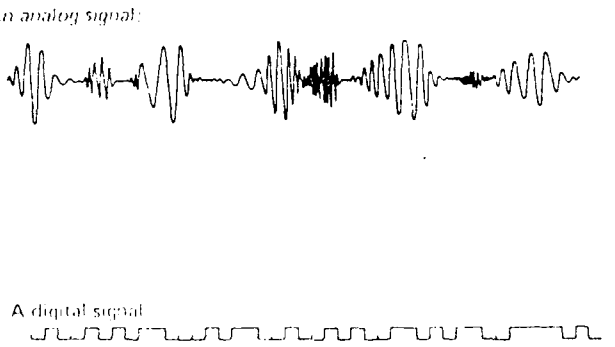

Figure 3. Analog and Digital Signals [Ref.:3]

Typically, digital communication involves the transmission of a stream of on and off pulses called *bits*. A digital transmission system is used to transmit digital signals, but it can also be used for transmitting analog data, using a specific device called *codec* (coder-decoder).

Finally, in order to achieve longer distances of transmission, *repeaters* are used, which restore the distorted from the attenuation signals, to their original shape and transmission level.

c. *Digital versus Analog transmission*

Most present day electronic and telecommunication equipment is still analog in nature. Digital transmission channels are becoming more widely used as the

impact of signal technology becomes greater and greater. Some of the main advantages of digital transmission are as follows:

(1) Digital Technology

The tremendous number of integrated circuit chips being produced and their low cost result in a cheaper implementation of many functions in digital form than in analog. This is due to the wide availability of the Large Scale Integration (LSI) and Very Large Scale Integration (VLSI) circuits, where thousands and tens of thousands circuits, respectively, are placed on a single silicon chip.

(2) Capacity Integrity

Digital technology is inherently more reliable by being less susceptible to noise than analog technology. This is due to the use of repeaters rather than amplifiers, so data is transmitted at longer distances while maintaining integrity.

(3) Capacity Utilization

The transmission of signals requires the provision of circuits with a very wide bandwidth. In order to utilize such capacity, a high degree of multiplexing is required, and this is achieved more easily and cheaply with digital rather than the analog systems.

(4) Security and Privacy

With the growing reliance on electronic data processing and storage, valuable information can easily be copied electronically through networks. Many techniques for hiding information while it is in transit have been evolved. These

techniques may be applied readily to analog and digital data that have been already digitized.

(5) Integration

The continuing growth in the amount of data being transmitted throughout the world results in a transition from analog to digital network systems. Thus, economies of scale can be achieved by providing a full range of services to users over a highly sophisticated, uniform, all-digital network. Much of this evolution is taking place within the framework of what is called Integrated Services Digital Network (ISDN).

2. Transmission media.

The quality of a transmission is determined mainly by the nature and the characteristics of the transmission medium used. Some of the most important characteristics and kinds of transmission medium are discussed below.

a. Classification of transmission media

Information can be carried over the links using several transmission media which can be classified as *guided* or *unguided*.

(1) Guided Media

A physical path used to guide the transmitted signals from the transmitter to receiver. Examples of such a media, are:

- *Wire pairs*. The original telephone and telegraph transmission media for both local and wide area networks. The wire itself can be copper or copper-clad steel.
- *Coaxial cable*. This medium can cover long distances and can carry more information than the wire pair. It consists of a single-wire conductor centered within

a cylindrical outer conductor. They are insulated from one another using various dielectric materials.

- *Optical fibers.* Applications of optical fiber systems range from short data links within a building to transcontinental systems. They can carry a huge amount of information, and are immune to most external sources of interference. Various glasses and plastics can be used to make optical fibers that are capable of conducting an optical ray.

(2) Unguided Media

Media such as the air and seawater, which transmit the signals without guiding them. Examples of systems using unguided media, are:

- *Microwave radio:* common for wide area networks, due to its effectiveness and cost.

- *Satellite links:* used for wide area networks, particularly over rough terrain, and for transcontinental communications.

b. Characteristics of a transmission media

A fundamental concept related to the transmission media, is its *bandwidth* or *capacity* depending on whether the medium carries analog or digital signals respectively.

(1) Bandwidth (BW)

Is the range of frequencies present in any given signal. The voice, for example, which is an analog signal, is spreaded over a range of frequencies from 20 to 20000 Hertz (Hz). This bandwidth contains voice frequencies that can be heard, and is also required for good quality audio reproduction. For economic reasons, telephone

companies transmit a bandwidth that varies from 300 to 3400 Hz only. *Wideband* analog links are also available using a bandwidth of 48KHz by grouping 12 voice links.

*(2) **Capacity***

Is the maximum rate of information transmission achievable on the link, and is measured as *bits per second (bps)*. Depending on the bps that links carry, they are classified as *low-speed* (110 to 1200bps), *medium-speed* (2.4 to 14.4Kbps), and *high-speed* (19.2 to 64Kbps) data links. The voice standard is 64Kbps using a *Pulse Code Modulation (PCM)* technique, while other existing techniques transmit at 32 or even 16Kbps.

*c. **Direction of information flow.***

This classification applies primarily to the network links. A link of transmission may be simplex, half-duplex, and full-duplex.

*(1) **Simplex Link***

Information is transmitted only in one direction, from one station (transmitter) to another (receiver). If two-way communication is desired, then a second link must be used for the return direction.

*(2) **Half-Duplex***

Information is transmitted in either direction, which means that both stations may transmit, but not simultaneously.

(3) Full-Duplex

Information is transmitted simultaneously in two directions, which means that both stations may transmit simultaneously.

3. Modulation

Modulation is the process of varying some characteristics of a signal called carrier in accordance with the information to be transmitted. There are several modulation techniques for analog or digital signals, while some of them are useful for both.

a. Modulation of analog data for analog signals

In the case of analog transmission, the carrier is a single-frequency sinusoidal signal which is modulated in accordance with the instantaneous values of the information to be transmitted. The most common techniques, are:

(1) Amplitude Modulation (AM)

The amplitude of carrier signal is modulated in accordance with the information to be transmitted. (Figure 4a).

(2) Frequency Modulation (FM)

The frequency of carrier signal is modulated in accordance with the information to be transmitted. (Figure 4b).

(3) Phase Modulation (PM)

The phase of carrier signal is modulated in accordance with the information to be transmitted. (Figure 4c).

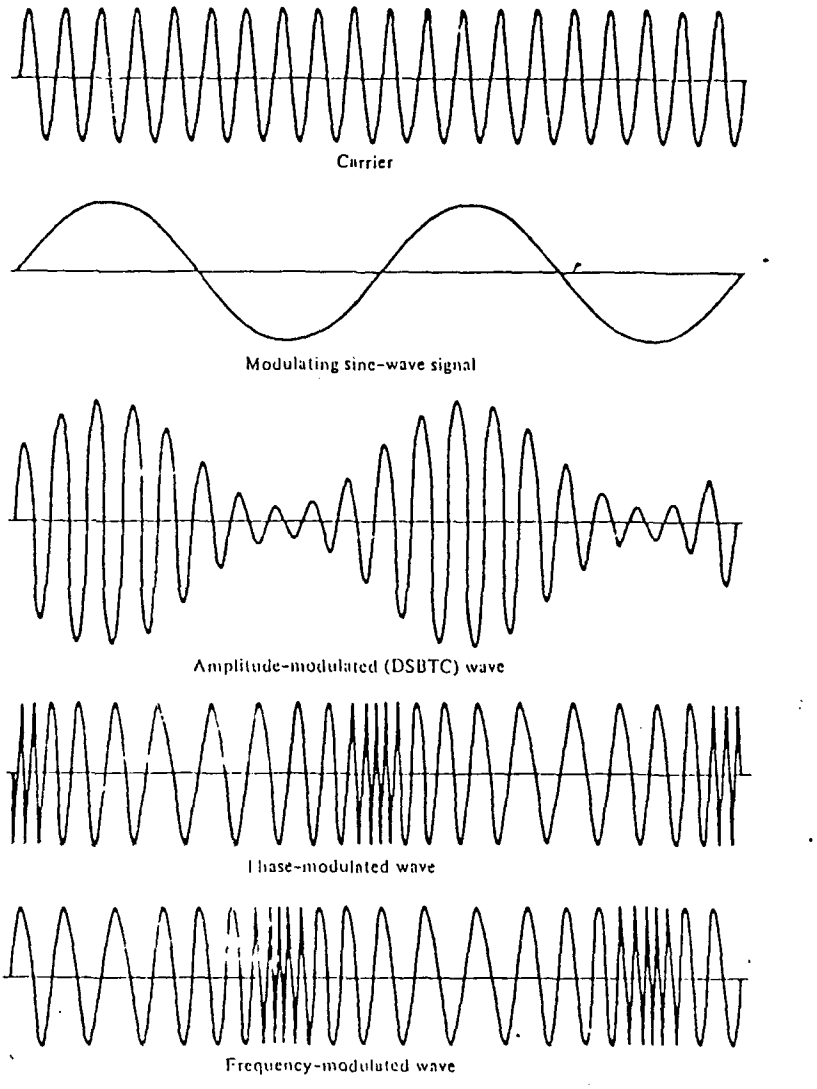

Figure 4: Modulation of analog data for analog signals [Ref. 4: p.93]

b. Modulation of analog data for digital signals

A second modulation scheme used in analog transmission is the sampled data technique. The primary objective of this process is to replace the analog signal by a sequence of discrete samples. This is done mainly for sharing the transmission medium with other signals, and for transmitting analog signals over digital links.

Each pulse of the sequence represents the information signal at a particular value of time. The conversion is done with a codec device. The most common forms of this modulation scheme, are:

(1) Pulse Amplitude Modulation (PAM)

The amplitude of each pulse of the sequence is proportional to the transmitted analog signal at the corresponding sample point.

(2) Pulse Width Modulation (PWM)

The width of each pulse of the sequence is modulated directly in accordance with the amplitude of the transmitted signal at the corresponding sample point.

(3) Pulse Position Modulation (PPM)

The position of each pulse of the sequence is modulated directly in accordance with the amplitude of the transmitted signal at the corresponding sample point.

(4) Pulse Code Modulation (PCM)

The most common form of this modulation scheme is pulse modulation. After the sampling an analog signal, the amplitude of each pulse is quantized into discrete amplitude levels. Each quantized value, in turn, is digitized to an eight digit binary number. The larger the number of quantization levels, the higher is the resulting quality of transmission.

(5) Delta Modulation (DM)

This modulation technique is characterized by a single binary digit representing the difference between successive amplitude samples. As the binary digit

represents only differences, which are smaller than the full amplitude, fewer bits are required to represent them.

c. Modulation of digital data for analog signals

The third modulation scheme is used for digital transmission. Like pulse modulation, it employs a sequence of pulses for the transmission of information. The pulses are of equal amplitude and duration and the information is transmitted by encoding the spacing between pulses as they are sent in sequence.

The most common digital modulation techniques are:

(1) Amplitude Shift Keying (ASK)

This is a form of AM where the binary digit 1 is represented by the presence of amplitude of the carrier frequency while the binary digit 0 is represented by the absence of amplitude. (Figure 5a).

(2) Frequency Shift Keying (FSK)

This is a form of FM where the two binary digits are represented by two different frequencies near the carrier frequency. (Figure 5b).

(3) Phase Shift Keying (PSK)

The phase of the carrier is shifted by 0° or 180°. The binary 1 is represented by the one phase of the carrier frequency and the binary 0 is represented by the other phase. (Figure 5c).

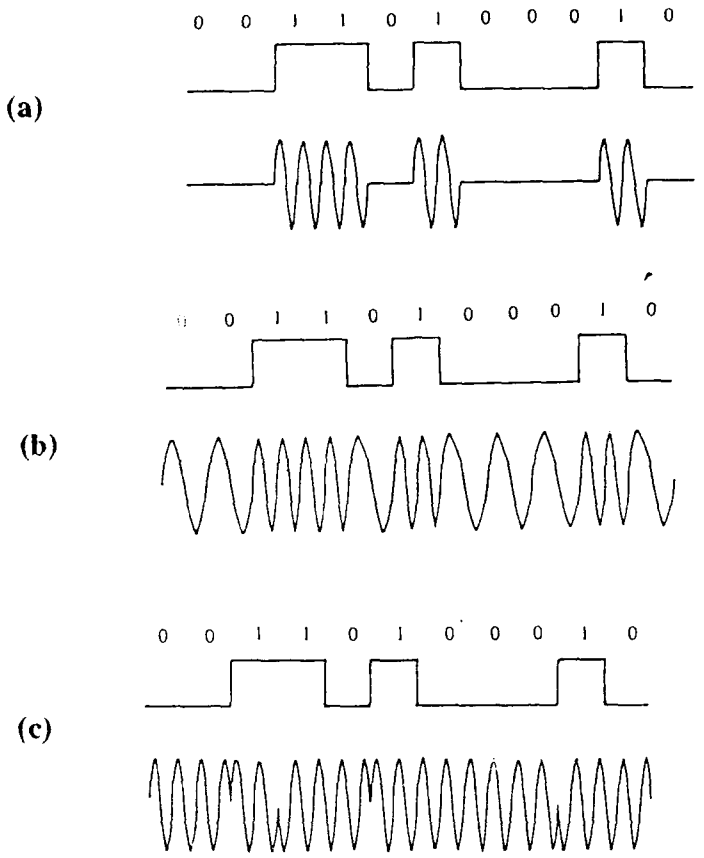

Figure 5. Modulation of analog signals for digital data [Ref. 4: p.76]

4. Multiplexing

Multiplexing is the use of one communication link to handle several channels of analog or digital data. The use of multiplexing techniques increases the utilization of the links and higher data rates may be obtained.

The most common multiplexing techniques, are:

a. Space Division Multiplexing (SDM)

Several physical links are grouped together to form a single larger, physical cable. This is feasible only for systems consisting of a few short links. An example of SDM is a wire-pair cable containing many hundreds of wire pairs. This technique is widely employed in the design of local networks due to the distortion resulting from crosstalk caused by wires packed close together. (Figure 8a).

b. Frequency Division Multiplexing (FDM)

Several frequency spectrums are combined to form a larger spectrum for subsequent transmission as a whole. This technique is suitable for multiplexing over 10,000 voice channels, which may be transmitted over long distances by a coaxial cable, and is used with analog data. (Figure 8b).

c. Time Division Multiplexing (TDM)

This combines several channels of binary information resulting in a higher rate channel of binary information. Many separate signals are multiplexed together, by a device called a *commutator*, which sequentially samples each data signal in order. The result of this process is a single PAM signal which can travel over a high bandwidth. At the end of the link, another device called *decommutator* routes the correct signal to its proper destination.

Pulse Modulation and Pulse Code Modulation techniques are suited for TDM. This technique is employed for short distances applications and has long been used with digital signals.

F. SIGNALING

The Public-Switched Telephone Network, as a telecommunication network, transmits *control signals* with the transmitting information. Control signals enable the switching offices to set up, disconnect, and control the transmissions. These signals may travel inside the voice bandwidth (*in-band*) or in a separate narrow signaling band (*out-band*) in the same channel with voice.

The generation and transmission of such signals is known as *signaling*. Signaling may be classified into two categories, based on the entities signaled between: user and local switching office, or between switching offices. Two subcategories in both cases are based upon the nature of information signaled: *address signals* (calling number) which direct the call to its proper destination and *supervisory signals* for the proper progress of the call.

1. User - local switching office signaling.

When a user wants to make a call, he sends a *calling signal* to the switching office. This is done either by generating loop-disconnect pulses equal to the dialed digit, when rotary dial is used, or by transmitting two frequencies for each dialed digit, when touch tone dial is used. The switching office lets a user know that a connection has been made to his line by sending a signal called *ringing signal*.

Finally, when the user has finished the call, the switching office is informed of it in order to disconnect the call and clear the line. This is done by a *clearing signal*.

In addition to the already mentioned signals, some other signals are needed for other functions, such as signaling a phone number (*dialing*), indicating that line is busy, etc.

2. Signaling between switching offices.

There are several types of signaling between switching offices. For short distances *direct-current (dc) signaling* is used, which is a low cost signal production. This type of signaling is only for local networks with a low signaling speed, 1.2 digits per second. In order to operate over greater distances, switching offices may connect user-dialed signals to other forms, such as *E-lead*, *M-lead*, and *battery-ground* forms.

The most common form of signaling is *multifrequency signaling*, with a signaling speed 6 to 10 digits per second. This form includes push button telephone instruments, where each button key transmits two audio-frequency signals simultaneously. Multifrequency signaling is an in-band signaling.

When data-processing machines are used over the PSTN, the signaling and data paths must be established in such a manner to avoid interference. Some systems use separate channels for data and signaling system. The signaling and data paths are completely separated. In this manner, a network can operate without having data links between every pair of switching offices. This approach is called *common-channel* signaling.

In other systems, where large groups of trunks are involved, PSTN may use data links that provide unlimited signaling capacity.

Data links may be used either by utilizing a voice-frequency link, using a modem, or utilizing a digital link with no need for a modem.

The last type of signaling between switching offices is the PCM signaling which can transmit 8000 digits per second. In-band signaling is transmitted over PCM links where PCM signals and TDM data streams are used for signaling purposes.

Generally, data-processing machines and modems are designed and used under restrictions that have been imposed in order to avoid interference between transmitting data and signaling.

III. PRIVATE TELECOMMUNICATIONS NETWORKS

A. GENERAL CONCEPTS

The Public Switched Telephone Network consists, basically, of two networks: the trunk circuits that interconnect the switching offices are regarded as the *main network* and the local loops that connect the devices to the local switching offices are regarded as the *local access network*.

In a local access network, the devices may be connected with the local switching office either directly or through a *private network* based on a private exchange.

A private network involves transmission, switching and signaling components that can be used only by a specific group of users and are not available to the general public. The specific users can communicate with one another using the private network, or they can use the PSTN's facilities through an interface between the private network and PSTN.

The interfaces are *switches* with internal and external calling capacity, and much effort is focused today on developing sophisticated switches to handle both voice and nonvoice devices.

The technical capabilities of a private network are evaluated on the basis of the provided capacity, connectivity, reliability, and quality.

The main concern of today's organizations is not whether to use public or private networks, or even how to successfully integrate the two, but how to use both to optimal advantage.

Both computers and communications are being driven by the continuing progress in the development of lightwave technology, integrated circuits and many new systems with huge capabilities that appear in the market.

Some of the most commonly used systems for private communications will be addressed in this chapter.

B. PRIVATE BRANCH EXCHANGE (PBX)

1. Architecture and Evolution

A PBX is a switching system which is located on the customer's premise and establishes communications paths between a significant variety of devices by receiving, processing and transmitting electrical signals. The devices may be telephones, data terminals, computers, other switching systems, image terminals, etc.

A PBX is composed of three main parts: the interfaces, the switching system, and the control system, as shown in Figure 10.

a. Interfaces

The interfaces are required to connect various types of analog or digital devices with the switch and to connect the switch with the PSTN or other switches. There are two types of interfaces: *line interfaces* and *trunk interfaces*. On the line side of the system, the subscriber's devices are connected to the PBX through the *ports*. Each interface can handle several ports, usually two, four or eight. There are a variety of types of ports to permit not only analog and digital phones but also data terminals, synchronous and asynchronous, with a wide range of speeds, to be interfaced to the system.

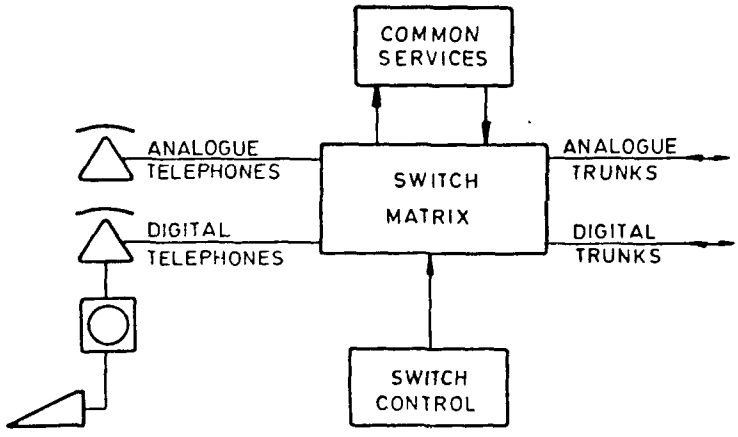

Figure 6: PBX Architecture [Ref 5: p.129]

On the trunk side of the system, the trunk interfaces provide the necessary functions to connect the various types of lines (trunks) coming from the local central office to the switch.

b. Switching System

The basic purpose of the switching system is to create and maintain a path for signals to travel between the interconnected subscribers.

According to its characteristics, PBXs have undergone four major evolutionary stages:

- The first generation encompasses electromechanical telephone switches based on step-by-step switches (SXS) and metallic crosspoints.

- The second generation involves the stored-program control PBXs where a stored computer program supervises a Time Division Multiplexed (TDM) semiconductor switching system. This kind of system is very flexible.

- The third generation involves the integration of voice and data in all digital formats using new digital protocols from the telephone to the same PBX-controlled network.

- The fourth generation products take the technology a major step beyond the simple integration of voice and data. The latest price over performance advances in Very Large Scale Integration (VLSI) promise a lot.

c. Control System

The control system is the brain of a PBX. It is a complete computer system which analyzes the control signals (dial pulses) from the devices in order to determine which path has to be established in response to these control signals. The major responsibilities of the control system, are:

- Coordinate the actions of the switching network, the device interfaces, and other network resources, in conjunction with the PSTN or other switching systems.

- Check several components of the system on a regular basis.

- Translate inputs received from the devices into actions that provide system services.

- Upon the completion of an established connection, release the dedicated devices or systems.

2. Classification of PBXs

The PBXs may be classified into two main categories according to the kind of matrix that is used: analog and digital PBXs. The latter may be further classified according to the implementation of their matrix, i.e., if it includes time division multiplexed buses, rotating memory, or crosspoint switches.

An *analog PBX* is characterized by the analog switching matrix that it contains and the analog signals transmitted throughout the entire system. When digital data is required to be transmitted through an analog PBX, a modem is used to modulate an analog carrier so that the digital data is represented in analog form. The modulated analog signal can then be switched by the analog switching system, and another modem at the receiving end to demodulate the signal back to its original form.

A *digital PBX* is characterized by the digital switching matrix that it contains. Through this matrix only digital data passes and analog signals have to be converted to a digital form. The digitized analog signals have to be converted back to analog form before they can be transmitted to the receiving device. The process of these conversions is performed by the line interfaces, when an analog device-digital switch connection exists, or by the trunk interfaces, when a digital switch-analog local central office connection exists.

The digital PBX is a mixed voice and data switching system. The continuously increasing need for data communications has led to the extensive use of such systems. Also, the wide availability of Large Scale Integration (LSI) circuits has made the digital PBXs an economical alternative.

3. Digital PBXs

Most of the PBXs installed today use digital technology both for the control functions as well as in the switching system itself. The main reasons for going towards an increasingly digital world are:

- Lower initial cost and lower annual charges.
- Improvement in transmission quality. By using digital TDM, instead of FDM, the losses have been reduced significantly.
- Flexibility to evolve to incorporate many new features that are demanded by the users.
- Smaller space requirements for installation.
- Significant personnel savings.

a. Stored Program Control (SPC)

One of the most important characteristics of digital PBXs is the Stored Program Control (SPC). It implies that the control functions are performed by a microprocessor or minicomputer. The stored program control provides a flexibility which results in a high degree of modularity of functions.

SPC increases the features and capabilities of the system quite easily by just installing new software releases. SPC also supports a lot of interface modules permitting a variety of devices to be interfaced to the system, such as digital phones, analog phones and synchronous and asynchronous data terminals, etc.

Many digital PBXs have more than one minicomputer or microcomputer to provide backup as well as to distribute the processing functions over multiple processors, thus reducing the vulnerability of the system and enhancing the system efficiency.

Computer based PBXs are used broadly today, because they offer many features that meet virtually any user requirements, and their capability to lower the overall telecommunication costs.

b. Digital PBX Features

Digital PBXs are very flexible and most of them provide the features that are listed below. Many other new features can be added easily to the system by programming. The features are classified in four major categories:

- System Features
- Attendant Console Features
- Station Features
- Instruments Features

(1) System Features

- **Additional I/O Devices:** the capability of the system to connect additional I/O devices via interfaces.
- **Alarm Indication - Major:** indicates that the system is in a non-operative state and system-failure transfer is active.
- **Alarm Indication - Minor:** indicates that the system is operative and has detected a minor failure.
- **Alternate Routing:** automatic routing of outgoing call when all circuits in the primary trunk group are busy.
- **Automatic Call Distribution (ACD):** when calls can be answered by any one of a group of stations, the calls are automatically distributed to the first free station.
- **Central Office (CO) Trunk Access:** the capability of the system to access the CO trunks by just dialing a digit, usually "9".
- **Daytime Trunk Control:** a specific trunk group can be restricted from access by stations for outgoing calls during daytime operation.
- **Dedicated Incoming Trunks (DIT):** permits a call to bypass the attendant console and ring to a preassigned internal station.

- **Direct Inward Dialing (DID):** outside callers can directly dial extensions within a company's PBX installation without using attendant assistance.

- **Flexible Intercept Facilities:** calls that cannot be completed because of class-of-service restrictions, or access code are routed to an intercept facility.

- **Flexible System Numbering Plan:** assigns the station numbers, trunk access codes, and feature access codes in accordance with a customer established numbering plan.

- **High Traffic Capacity:** indicates that the system is designed to be non-blocking.

- **Least Cost Routing (LCR):** a call is routed to a number accessible via a corporate network by whatever is the cheapest route.

- **Line Lockout:** whenever a telephone handset is left off-hook, listening to dial tone, busy tone, intercept tone, etc., for longer than a predetermined period of time, the system automatically releases the station from the switching equipment.

- **Manual On-Line Maintenance Test:** test programs that verify correct operation of the peripheral equipment.

- **Memory Support:** in a power failure, an optional memory support battery supplies the necessary power to maintain the RAM for a minimum three minutes.

- **Music or Advertising:** a means through which the system interfaces with customers in the "hold-call" conditions.

- **Night Service Automatic Switching:** switches a call into the night service mode if it remains unanswered for a predetermined period of time.

- **Station Class-of-Service:** each station in the system has a class-of-service code which can allow or deny access to any combination of features included in the system.

- **Station Message Detail Recording (SMDR):** a means for managing calls and reducing telephone abuse.

- **Station-to-Station Calling:** any station user can dial any other station within the system without the attendant assistance.

- **Tandem Switching:** the connection of a telephone company trunk to another telephone company trunk through the switch.

- **Traffic and Feature Usage Measurement:** the capability of automatically or manually monitoring various system operations for which traffic and features usage information is desired.

- **Voice Mail Interface:** allows the system to interface with voice mail systems.

(2) Attendant Console Features

- **Alert Burst Attendant Indication:** a single burst of tone in the attendant's headset, when he/she is busy, alerting the attendant to another incoming call.

- **Attendant Control of Station Dial Restrictions:** the attendant can change temporarily the class-of-service of an individual station via the attendant console.

- **Attendant Selective Answering Priority:** the attendant can manually select among Incoming (INC), Recalls (REC) and Operator (OPR) calls.

- **Automatic Recall:** the attendant is automatically recalled on calls held by the attendant, or unanswered past a predetermined period of time.

- **Busy verification of Station Lines:** the attendant may verify whether a station line is busy, idle, or in an out-of-service state.

- **Call Hold:** the attendant can place a station or trunk call on hold in order to place another call, or to do something else.

- **Call Type Display:** the types of calls are visually displayed, allowing the attendant to answer each call with an appropriate response.

- **Call Waiting Indication:** a visual indication for the attendant that calls are waiting to be answered.

- **Called Station Number Display:** when the attendant places a call to a station, the extension number and class-of-service of the called station are displayed.

- **Camp-On:** the attendant can extend a trunk call to a busy station. The trunk party is automatically placed in a waiting mode while a call-waiting tone is directed to the busy station.

- **Conference:** allows the attendant to establish a conference of up to seven parties.

- **Console Operation:** incoming calls are uniformly distributed among the attendants' consoles.

- **Direct Trunk Access:** the attendant can select and access individual trunk circuits.

- **Extension of Calls:** the attendant may extend all types of incoming calls to a station or to another trunk.

- **Least Cost Routing Route Number Display:** for systems provided with the LCR feature, a visual display of the route taken by the attendant completed outgoing calls is provided to the attendant.

- **Override:** allows the attendant, when connected to an incoming trunk call, to enter into an existing busy station-to-station or station-to-trunk connection and inform the station user about the waiting trunk call.

- **Trunk Group Indicators:** leds are provided to indicate the busy/idle condition of trunk groups.

(3) Station Features

- **Add-On Conference**: allows a station user to add a third party to an existing two-party connection.

- **Attendant Override Security:** stations assigned this feature may not be overridden by the attendant.

- **Automatic Callback On Held Call:** a trunk call that remains on hold beyond a predetermined period of time is automatically recalled to the station that held the call or to the attendant.

- **Automatic Call Forwarding (ACF):** when a person goes to a different location and informs the system of the new extension number, then the system forwards calls to the new location.

- **Call Hold:** allows a station user to place any call on hold and hang up without loosing the call.

- **Call Park:** allows a station user to place a station or trunk call on "system hold" and return to the parked party from the same or another station.

- **Call Tracing:** allows a station user to have certain call data recorded on a device, such as a printer.

- **Call Transfer:** allows a station user engaged in a two-party talking connection to transfer the other party to another destination.

- **Call Transfer Security:** if a trunk call is transferred from one station to another, and the second station does not answer within a predetermined period of time, the system recalls the held party to the station that originally transferred the call.

- **Data Line Security:** stations assigned this feature may not be overridden or camped on when the station is busy.

- **Dial Access to Attendant:** the attendant can be accessed by dialing just a code, usually zero (0).

- **Distinctive Ringing.** several types of distinctive ringing patterns are provided to allow station users to distinguish between the different types of incoming calls.

- **Do Not Disturb:** makes the user's station appear busy, if the station user wishes not to be disturbed.

- **Hold to Attendant:** allows trunk calls held for station transfer to be routed to the attendant instead of the transferring station.

- **Hot Line Service:** allows stations to be programmed for automatic dialing of a predetermined destination number upon the station user going off-hook.

- **Internal Call Queuing - Callback/Standby:** a station user, after dialing a busy station, is placed in a queue to be called back or is placed in a special standby queuing mode.

- **Last Number Redial:** allows the last number dialed from a user's station to be automatically redialed.

- **Terminate Only Service:** a station assigned this feature is allowed to receive calls only.

- **Voice Mail Interface:** allows the system to interface with voice mail systems.

(4) Instrument Features

- **Abbreviated Dialing:** frequently called or emergency numbers can be dialed by pressing fewer buttons than if the number were dialed one digit at a time.

- **Attendant Identification on Display:** dialing or receiving a call from the attendant, his/her identification number or indicator may appear on the display of the instrument.

- **Automatic Answer:** applies to station-to-station, Automatic Intercom and Executive Intercom calls.

- **Automatic Intercom:** provides a talking path between two designated instruments with automatic signaling of the called instrument.

- **Call Park Location Number Display:** a station user that parks a call is provided with a display that identifies the location of the parked call.

- **Call Privacy:** prevents all other parties from bridging on that line.

- **Call Transfer to Attendant:** a station user engaged in an incoming or outgoing call may transfer the call to the attendant for further assistance by pressing just one button.

- **Call Waiting Display:** a display that includes the call waiting indicator and the station number or trunk identity of the call waiting to be answered.

- **Direct Station Selection:** allows automatic dialing of a preassigned station number.

- **Exclusive Hold:** allows the station user to place a call in a special hold mode, such that only the station user that held the call can retrieve it.

- **Forced Call Forwarding:** allows the station user to forward a waiting or ringing call to a preassigned station.

- **Incoming Call Display:** displays the source of the calling party.

- **Multiple Pickup:** allows a user to have access to several lines.

- **Timed Reminder:** provides the instrument user with a time alarm-type alert.

- **Voice Announce:** establishes a one way communication path which allows a calling party to be heard over the called party's instrument's built-in speaker.

4. Advantages of PBXs

- High level of security.

- Substantial concentration. The number of the required wire pairs is smaller than that of the served phones.

- High reliability.

- Uninterruptible power source.
- Very efficient for voice traffic.
- Data rate of 64Kbps for synchronous digital voice or data, and 19.2Kbps for asynchronous.
- Well proven technology
- Provides long haul interfaces to communications systems around the world through the PSTN.
- Nonblocking capabilities, (i.e., dedicated port assignments are used for all attached phones).
- No network delay once a connection has been made.
- Using digital technology takes advantage of low cost LSI and VLSI.
- Encryption capabilities.
- Can handle an evolution to the Integrated Services Digital Network (ISDN)[1].

5. Disadvantages of PBXs

- Lack of adequate data-switching capability.
- Not fast enough to support data terminals.
- Minimal protocol conversion
- Very limited computer-to-computer communications, high resolution graphics, facsimile, and high-speed file transfer.
- Minimal emulation support.
- Limited resource sharing of print or file servers among terminals.

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[1]A projected worldwide public telecommunications system. It does not exist yet and is defined only by an evolving set of standards.

C. CENTRAL EXCHANGE (CENTREX)

1. Overview

The Centrex is a large capacity exchange providing a set of communications services to users requiring from one to thousands (100,000) of lines providing efficient and low-cost telephone service. The equipment used by the Centrex is located at the local switching office and not on the subscriber's premises, hence the origin of its name; **centr**al **ex**change.

Actually, there are two kinds of Centrex services: the *Central Office (CO) Centrex* and the *Customer Centrex (Centrex CU)*. In the first, the services are provided to customers by the switching equipment of the public exchange; while in the second, which has been almost eliminated, the system is a private exchange which can be shared by several organizations, geographically close to one another.

Centrex services are provided by both analog and digital central offices and any modernization of the COs increases Centrex capabilities. The local telephone companies are responsible for any technological improvement of a CO without charging the subscribers. The subscribers are charged only for the use of the system and the rates are based on the selected features, the distance of the station from the CO, the size of the line, and the length of the service contract.

The features provided by such a system depend upon the type of switching equipment located at the CO.

2. Digital Centrex

Digital Centrex is provided by the digital COs where a digital switching system provides computer-controlled time-division switching. It can support a distributed architecture that uses many microprocessor-controlled switching modules.

Direct interface of digital carrier systems can be handled directly by the digital COs. Interface with the T1 carrier provides a multiplex of 24 digitized voice channels using a two-pair wire at 1.544Mbps.

The features that are provided by such a system are similar to those of the digital PBXs. The capability to access the ISDN services enables users to use the same interface for different types of terminals and applications.

3. Data Communications

Local Area Network requirements can be satisfied by the CO LAN service which is provided by either an analog or digital CO. More precisely, a data switch located in the local CO provides CO-LAN service. Such a data switch can connect data terminals and the host computer to the subscriber premises via private line facilities. It can also support the RS-232-C interface, which handles asynchronous (1.2Kbps to 19.2Kbps) and synchronous (56Kbps) transmission speeds.

Some of the main advantages of the CO-LAN type services are the lower end-user cost for data transmission, and the minimization of the required power, environmental requirements and subscriber floor space.

4. Advantages of Centrex

- Appropriate for small and large network users and able to serve from one to more than 100,000 lines at one or more locations.
- Provides voice and data services.
- Provides nonblocking traffic.
- Supplies uninterrupted backup power.
- Operates and is maintained 24 hours per day under the responsibility of the local telephone company.
- Any technical advances do not economically affect the user, while the system capabilities are increasing.
- User can easily activate and deactivate features according to his/her needs.
- Technical or other problems occurring in subscriber's premise do not affect the Centrex lines.
- No space is required for switching and power equipment on the subscriber's premises.
- Capability to provide ISDN services.
- Increased flexibility relative to subscriber moves.
- The provided dial service eliminates the need for operators to process the calls.
- Compatibility of the available products.

5. Disadvantages of Centrex

- Security, is not provided as the switching equipment is not located on the subscriber's premise.
- Not available in all areas, and where it is available it may not provide all the required features.
- Distance between subscriber's premise and local CO, as each line is charged according its length in miles.

- COs modernization takes a considerable amount of time and also depends upon the number of subscribers and the location of the CO.

D. LOCAL AREA NETWORK (LAN)

1. Overview

Many organizations face problems as their data communications facilities evolve. For example, separate networks for different kinds of terminals may not be enough to cover their needs, and the maintenance and extension of these networks may be increasingly expensive.

Problems such as inability to use existing terminals to access incompatible computers, the lack of space in ducts, the dependence of the network on the host computer, the lack of peer communications facilities, and many others, made organizations look for a unified approach to data communications that would enable them to avoid these problems.

This increasing need to interconnect heterogeneous devices, and the enormous advances in digital electronics, led to the development and growth of the *Local Area Network* (LAN).

The term Local Area Network (LAN) refers to a digital communication system that provides interconnection of a variety of data communicating devices within a small area. The communicating devices may be terminals, minicomputers, microcomputers, host computers, mainframes, etc.

Some of the major characteristics of a LAN are:

- The transmission of data between user station and computers. It is also possible to transmit voice and video.
- High-speed operation with a transmission rate range from 1Mbps to 20Mbps.
- The LAN channel is owned by the organization using the facility.
- A LAN is used within a building or between buildings on a campus, a large manufacturing facility, or any other multi-building configuration.
- High reliability and low error rate.

2. LAN Architecture

The major components of a LAN, are: the transmission medium, the connector, the transceiver, the controller, and the user station.

The *transmission medium*, is the physical path between transmitter and receiver, and may be wire pairs, coaxial cable, or optical fiber; the *connector* or *tap*, is the interface between the medium and the user station, and may be a single cable television (CATV), infrared diodes, microwave antennas, or laser-emitting semiconductors for optical fibers; the *transceiver* encodes the data and drives the medium at high speed; the *controller* performs addressing, formatting, buffering, and error control functions; finally the *station* is the actual user terminal equipment.

The nature of a Local Area Network is determined mainly by three factors: the transmission medium, the topology and the medium access control protocol. The first two factors together determine the type of data that may be transmitted, the speed and efficiency of communication, and even the kinds of applications that a LAN may support. The *medium access control* provides some rules for determining which station is allocated

to use the network at any particular line. It is considered the most important classification from a performance standpoint.

The data may be transmitted at *baseband* or it may be modulated to produce a *broadband* LAN with several different frequency bands.

3. Classification of LANs

The LANs are classified mainly in two broad categories, according to whether they use digital or analog technology: broadband and baseband respectively.

a. Baseband LAN

A Local Area Network which uses digital signaling is referred to as a baseband LAN. This kind of network uses digital technology. Multiple access to the medium can be provided by a Time Division Multiplexer (TDM), since the entire frequency spectrum of the medium is used to form the transmission signal.

The transmission is bidirectional and only one cable is used for that. The most common media in use are coaxial cable and the twisted pair.

The coaxial scheme is implemented with 50 ohm cable and a maximum length of 500 meters. The data rate of the system is defined by the distance between any two of the attached cable taps, the number of taps, the cable length, and the electrical characteristics of the system components.

b. Broadband LANs

Broadband systems use analog technology. A high frequency modem introduces a carrier signal on the transmission channel. The carrier then is modulated by

the user's digital signal. Multiple channels of voice, video, or audio are provided in one path using FDM.

Broadband LANs use 75-ohm coaxial cable (CATV) that is capable of carrying analog signals over a wide range of frequencies up to 400MHz.

The topology used is that of a tree, where signals are applied to the cable at the taps and travel in a single direction. It is also possible to use two parallel cables throughout the tree structure, looped together at the ends. Amplifiers are inserted periodically in the cable system to maintain signal levels.

4. Advantages of LANs

a. Broadband systems

- Security using encryption techniques.
- High speed and low bit error rate.
- Highly reliable components (CATV).
- Better noise immunity because coaxial cable is used.
- High capac The same media can carry multiple channels (voice, data, tv).
- Geographic independability as gateways permit access to external systems.
- Control flexibility as the control mechanisms can be different (distributed or centralized) for each channel.

b. Baseband systems

- Inexpensive system.
- Simple installation.

5. Disadvantages of LANs

a. Broadband systems

- High cost of RF modems.
- Complexity
- Propagation delay.

b. Baseband systems

- Low data rate.
- Use of only one transmission channel.
- Limited distance between the terminals.

E. CONCLUSIONS

A choice among the above mentioned systems can be difficult and no one can recommend one or another system as the generally best solution because the communications requirements are not the same for all kinds of organizations.

All the systems have strong and weak points to offer and many of the offered features are virtually the same.

After an organization has established its communications requirements, many other factors have to be considered in order to determine which system best suit its needs.

Some of the most important factors that have to be considered are:

- Physical location of the equipment. (User's premise vs. local switching office.)
- Cost-performance ratio.
- Analog or digital technology.

- Lease or buy.
- Many single networks or one large complex network?
- Ease of installation and use.
- Compatibility.
- Accessibility.
- Reliability.
- Maintainability.

IV. A PRIVATE TELECOMMUNICATION SYSTEM APPROACH

A. WHY PRIVATE COMMUNICATION SYSTEMS?

Today, more and more executives view private communication systems as the means of their organizational efficiency and productivity. Some of the main reasons that lead them to such a viewpoint are:

- The predominately local nature of organization communications, both voice and data. More precisely, about 50% of an organization's communications take place within one building or campus, and about 25% go no further than 60 to 70 miles.
- The proliferation of computer terminals, personal computers, and other intelligent office equipment has increased the demand for more efficient and flexible data communications capabilities, which are provided more easily by private communications systems.
- The greater control over domestic communications that can be achieved by such systems.
- The ability of private communication systems to handle nonstandard aggregate rates, nonstandard data channel rates and asynchronous data rates.

However, private communication systems also have their share of disadvantages, including lack of uniformity, interoperability, and true interconnectivity to service provider network elements.

The mix of advantages and disadvantages complicates the choice of a communication system. Planning a private communication system is a complex engineering task.

B. TELECOMMUNICATIONS PLANNING

In recent decades, the importance and complexity of telecommunications planning has grown immeasurably for any kind of *organization*[2]. The scope of available services has substantially widened, and the range of existing or latent technological options is constantly growing. The level of investment and resources committed is now a major financial concern.

In addition, many organizations recently experienced rapid business expansion. To meet this growth, either new telecommunication facilities have to be installed or existing facilities must be expanded in newly occupied buildings. This expansion into new locations needs a planning as to how voice and data communications should be provided and how data processing resources and specialized data devices have to be connected.

There is an orderly process by which an organization can plan on its telecommunication systems. This process starts with analyzing companywide needs (requirements definition), proceeding through listing problems, proposing several solutions, preparing a request for proposal (RFP), vendor selection, test and rollout, and ending with some post-implementation followup.

More precisely, the process of planning for telecommunication systems can be broadly divided into three phases: strategic, procurement and utilization. *Strategic planning* is concerned with preparing for the telecommunications opportunities that are expected in the long term, i.e., for five years or more ahead. *Procurement planning* is

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[2]This word is used in the rest of this document to represent a number of organizations, including universities, agencies, military bases, hospitals, and so forth.

concerned with deciding the level and timing of investment in new systems and in enhancing and developing existing systems normally up to five years ahead, and in procuring and commissioning them when needed. *Utilization planning* is concerned with ensuring the telecommunications systems and other resources acquired are used in the most efficient way to meet communications needs.

The rest of this thesis will give some guidelines to an organization which has a poor and obsolete telecommunication system, highly dependent on the PSTN, and considers a substantial system expansion in its strategic plan over the next five years. This specific organization to be described below will be referred to as *target organization* hereafter. What is examined and proposed for target organization can be applied to numerous other organizations of a similar size.

C. THE TARGET ORGANIZATION

1. General description

The target organization is a large manufacturing company which is located ten miles south of a small city and is housed in seven buildings spread over approximately half a square mile.

The main five-floor building, where the headquarters are located, is in the center of the premise. The rest of the buildings are spread around it.

Four buildings are situated on the south side of the main building, two of which are the laboratories of the corporation and the other two the warehouses. On the west side, there is a three-floor building where the marketing and finance departments are

located. On the east side, there is a four-floor building where the sales, processing and other services departments are located. The overall distances between the buildings vary from a minimum of 600 teet to a 2,000 foot maximum.

2. Organizational Structure

Target organization employs about 1,000 people divided into five distinct departments that are structured by function. Each department brings together all those functions engaged in one activity or several related activities, and a vice-president is in charge of each organizational function. All vice-presidents report to the company's president.

The departments and their functional activities are:

- **Research and Development (R&D):** It has responsibility for new product generation and development, screening, approval, and guidelines that define the manufacturing process before a new product goes into large scale production.
- **Marketing:** It is responsible for the sales (control, forecasting, etc.), customer orders, contracts, pricing, applications engineering, market surveillance and agents.
- **Manufacturing:** It is responsible for manufacturing products, manufacturing technology and directions, product specification, test facilities, cost analysis, operations, raw materials, and finished goods.
- **Finance:** It is responsible for the economic evaluation of the corporation, dealing with payrolls, credits, accounts receivable, accounts payable, and general ledger.
- **Personnel:** It is responsible for the employees, dealing with work productivity, job satisfaction, quality of work, strength and professionalism of employees, morale, accident rate and employees records.

The employees, according to the nature of their job functions, are classified into five main categories: managerial, professional, secretarial, clerical, and working staff. The major activities performed by each category are described below.

- **Managerial staff:** internal and external voice communication, manipulation of statistical and numerical data involving access to the organization's databases, communication of graphical information, planning, scheduling, decision making, etc.

- **Professional staff:** internal and external voice communication, manipulation and communication of graphical information, mailing, filing, document processing, planning, scheduling, accessing the organization's databases, etc.

- **Secretarial staff:** internal and external voice communication, typing, mailing, retrieving, filing, reading and processing documents, scheduling, document or note distribution, etc.

- **Clerical staff:** internal and external voice communication, searching, retrieving, filing documents, accessing the organization's databases, processing documents, etc.

- **Working staff:** production, storing, delivery of finished goods, etc.

All the above described departmental and employee activities, except those related to working staff, are heavily dependent on computers and telecommunications. For this reason, the buildings are linked by telephone and hardcopy computer output.

3. Current telecommunication system

The target organization's current telecommunication system is the result of an evolving system dating back to 1968. It consists of separate networks having very little if any interoperability.

On the voice side, the organization uses the *Key Telephone Service (KTS)* provided by the public telephone company. This service, defined as a customer-controlled switching system, provides key-selected access at an employee station to a multiplicity of lines for internal and external communication. Stations are telephone sets that have a number of depressible keys. Associated equipments used to be in a cabinet located at the

corporation's main building. Recently, the target organization started to use telephone sets that have the associated equipment built internally in the sets.

Depressing an appropriate key, an employee can select any line, out of six, terminated on his\her instrument. The majority of the organization's instruments, about 85%, are connected with the local central office for the local calls, and with the Wide Area Telephone Service (WATS)[3] for long distance calls. Finally, each station is connected with a few, up to a few dozen, other stations for internal communication needs.

The major features provided by target's KTS, are:

- **Pick-up.** An employee can pick-up a call on any line terminated on his/her instrument.
- **Hold.** An employee can hold one line off-hook and can talk on another line.
- **Intercom.** An employee can be connected to one or more other employees through dedicated channels, without the need for placing the call through the local CO.
- **Conferencing.** An employee can establish a 3-way call by simultaneously using two of the lines that appear at his/her station.

Other than the KTS, target uses common telephone sets accessing the PSTN for local and long distance calls.

On the data side, target has 40 microcomputers (personal computers) from various manufacturers. Thirty of them are stand-alone and the rest are connected with coaxial cable of a bus configuration. In order to control the contention by multiple stations, the Carrier Sense Multiple Access/Collision Detect (CSMA/CD) access technique

[3]A volume-discount service with its rate dependent on the volume of calls. Special private-access lines are used to connect to the PSTN via WATS- equipped central offices.

is used. This access protocol checks to see if a line is busy with someone else transmitting data. If not the station seizes the line. All attached stations hear the message that p sses by, and check to see where it is addressed.

Using modems, microcomputers can communicate over the telephone lines and can exchange information with host[4] computers.

In addition, the target organization has 20 printers from various manufacturers. Sixteen of them are stand-alone and the other four are connected by coaxial cable and shared by more than one employee.

Finally, the organization has five stand-alone word processors to create, modify, duplicate, file, delete, and store text within each of the organization's department.

4. Problem Definition

Today, the target corporation is in an undesirable situation where both overall efficiency and that of individual employees are stagnant, and the effectiveness of facilities is deteriorating continuously. In addition, complaints are rising from almost all the departments about the inability of the existing communication system to meet their requirements. Issues have been raised regarding capacity, cost, rate of expansion, and the ability to properly fulfill the requirements. The primary data communication system has marginally evolved and expanded to meet an increasing number of employees. However, the corporation's growth has been so rapid that the equipment's capacity has frequently

[4]A computer, not necessarily a large one, that performs application processing, accessing bulk memory and storing data bases.

been exceeded. At peak times, when most employees want to use the system, it is blocked and unavailable.

The system reliability is not adequate for production use primarily due to the numerous failures of the communications circuits. Failures range from transmission errors to circuit outages that require telephone company intervention.

Furthermore, some of the microcomputers and telephone instruments have not been manufactured or marketed for ten years or more; mileage charges that are applied to every line by the telephone company are very high; security is not provided as the telecommunication system is highly dependent on PSTN; and features needed to reduce telecommunication costs and increase productivity (e.g. Direct Inward Dialing (DID), Direct Outward Dialing (DOD), etc.) cannot be achieved by the current system.

All these problems, the multiple forces of business needs, the various technological advances, the need to move from a situation which is highly dependent on PSTN toward an internally owned utility, and the corporation's projected growth led the target organization to appoint a task force to determine what is needed to provide a robust telecommunication system that will accommodate and complement its growing needs. The overall problem requires the consideration of many different aspects and factors, all of which cannot possibly be considered simultaneously.

5. Future Telecommunications Plans

The target organization's strategic plan for the next five years indicates that the company is planning to purchase some modern communication equipments and devices in order to increase its overall productivity.

Among the most important devices that will be purchased are:

- **Minicomputer.** A computer with more computer power than a microcomputer but less than a large mainframe computer. This is going to be connected with the corporation's microcomputers.

- **Intelligent Computer Terminals.** Devices that support standard applications including order and data entry, computer inquiry and response, etc. These devices are very flexible and can be switched to several different computers for different applications as well as being switched to external services.

- **Dumb Terminals.** Devices that serve as simple input/output devices to enter and receive data interacting with the minicomputer. They send, receive and display all characters of the alphabet, as well as numbers and symbols, but they can not manipulate the data in any way.

- **Graphic Terminals.** Devices that are used to display computer-drawn pictures. The screen of such a terminal functions in the way a television tube does, being able to display just about any character or figure that can be created by a computer. They will be used in executive and professional offices where high-level decisions are made.

- **Printers-Copiers.** Devices providing printouts or multiple copies of a document produced by a computer or a word processor respectively.

- **Laser Printers.** Devices producing high-quality output from text or data generated from a word or data processing system using the media of magnetic cassettes, cards or diskettes. They also have the ability to integrate undigitized hard copy originals with stored and digitized text and graphics.

- **Facsimile (FAX).** Machines allowing images to be transmitted via wire or broadcasting. It is equivalent to putting materials into a photocopy machine at one end of the line, and having the copy come out at the other. It can readily transmit graphics, any type of image, and even photographs as part of a message.

- **Word Processors.** A special purpose computer designed to do only word processing tasks. They perform automated processing or manipulation of words.

All these new communication devices, plus the already existing hardwares, have to be interconnected in order to exchange information. It is vital therefore to approach a private communication system through a detailed planning.

D. PLANNING A PRIVATE TELECOMMUNICATION SYSTEM

Those people involved in such a planning have to take into consideration the following factors:

- The organization's current telecommunication system.
- The organization's future needs and devices that will be purchased.
- The current available technology in telecommunications.
- The already existing features and hardware that can continue to be used.
- Major advanced features that can reduce telecommunication costs and increase the productivity of the company.

Detailed planning, considering the above factors, can be achieved using the following steps:

- Formulation of a selection team.
- Initial project plan.
- Definition of requirements.
- Possible alternative solutions.
- Request For Proposal (RFP).

1. STEP ONE: Formulation of a "Selection Team"

The first step of Target's planning is to form a team representing a cross-section of management and technical specialists. The team members have to represent every department and they must be organized into technical, business/financial and legal/regulatory categories. For better results, an external consultant is recommended.

2. STEP TWO: Initial Project Plan

After the selection of team members, the team has to collect data from all the departments in order to prepare an initial project plan. The initial project plan develops an accurate description of the existing telecommunication system of the corporation and how it is operated.

Data collection can be achieved by observation, interviews, and questionnaires. Observation can take the form of "walking through" the system, and the results can be recorded in tabular and graphic form. Interviews with people who use or run the system, such as telephone switchboard operators, individual telephone users, data processing staff, etc., can be of great value. Finally, questionnaires ask questions on paper, making it possible to reach a larger numbers of users.

3. STEP THREE: Definition of Requirements

After developing the initial project plan, the team has to examine and state the corporation's voice and data requirements. The summary of the collected data, together with a list of capabilities and features which might continue to be used and the estimation of the corporation's growth and consideration of future plans, will determine target's requirements.

a. User Requirements

The activities performed by each category of employee gives an initial list of potential requirements that must be provided by the communication system. The various forms of information that are communicated within the corporation (e.g., internal

and external voice communication, mailing, searching, retrieving, filing, scheduling, financing, etc.) can be supported by the following system features:

- **Voice:** Systems involving the standard telephone and the requirements for switching voice. Today, many voice features make telephone communications faster, more convenient and solve the telephone tag problem[5]. These features range from the basic, such as Direct Inward Dialing (DID), Direct Outward Dialing (DOD), Voice Store and Forward, Call Privacy, Hold Transfer, Automatic Intercom, to more sophisticated features or others intended for particular situations or users.

- **Data Communication:** Systems transfering encoded information from one location to another by means of a communication channel. The sending and receiving units are usually computers or terminals. These systems provide immediate access to information when it is needed, more efficient operation of organizations over a wide geographic area (campus), centralized control of organization's data, and rapid transmission of information.

- **Data Processing:** Systems collecting, processing and distributing data (numbers mainly). These systems can be organized in one of the following ways: *centralized*, consisting of a large central processing unit supporting a variety of peripheral devices, providing the advantages of cost savings and data security; *decentralized*, consisting of a single minicomputer and its associated peripheral devices, providing the advantage of local autonomy; *distributed*, consisting of a communications network connecting centralized and decentralized computers, reducing the processing costs and cabling requirements in multiple buildings.

- **Word Processing:** Systems providing automated processing or manipulation of words by the computer. The direct and easy access of stored data improves the economics, the speed and the quality of document-based communications.

- **Electronic Mail (E-mail):** Systems using as input devices the word processing systems. It is characterized by three basic functions: formation, sending and reception of messages. Each user is assigned a "mail box" and messages are directed by the user's name. It is easily accessible from any telephone and is very helpful for managers and professional staff. Provides security for storage, access and distribution. Reduces copying and improves the speed of communications.

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[5]Telephone tag involves the waste of time trying to contact someone to receive or relay information.

Considering the features described above, the functions already provided by the current system, together with some more general basic user requirements, a list of user requirements may be summarized as follows:

The communication system must provide:

1. Advanced voice features, such as: DID, DOD, voice store and Forward, etc., to solve the telephone tag problem and reduce the corporate telecommunications cost.

2. Efficient and reliable switching of data, enabling employees to gain access to host computers, applications and databases.

3. A distributed data processing capability to reduce the cabling requirements and processing cost.

4. Capability to support multiple word processors, to share resources, such as printers, among several users.

5. Simplicity in use (user friendliness) to be used by all employees.

6. Electronic mail boxes to connect electronic mail users to exchange messages.

7. The capability to interconnect users to transmit data and have access from any terminal to the installed host and databases.

8. The capability for all employees to share expensive peripherals, such as: laser printers, facsimile, that are attached on the system.

9. Responsive, accurate, effective, and affortable support to user's needs.

List of User Requirements

b. Transmission Requirements

A user workstation may consist of a number of microcomputers, printers, terminals, word processors, and facsimiles. These devices can communicate with each other and with the minicomputer. They can also be connected to the company's telephone dial network in order to provide employees with the capabilities to (1) manage information, prepare and send messages to other computers, (2) prepare and send correspondence to customers, (3) maintain weekly and daily schedules, search, retrieve and file documents, etc.

Such applications impose different requirements on the communication systems for different organization. Some of the devices are able to work independently of one another or jointly. Some of the applications are low volume while others require large volumes of data to be transmitted in a short period of time.

The target organization's daily activities involve, among others, the generation of proposals, purchase orders, invoices, manuals and quotes of five to approximately two hundreds papers per day.

If it is assumed that a single $8^1/_2$ X 11 page contains of 24 lines with 80 characters per line, the total number of characters per page is 1920 characters. Representing each character by eight bits, the total number of bits per page is about 15.4Kbits.

With the above assumptions, an analysis of transmission requirements for some of the discussed applications is made below.

- **Connecting Terminals and Computers:** Under the assumption that a typical screen has the same size as the above discussed page, a commonly accepted response time, i.e., user-terminal interaction, is three seconds. A screen consisting of 15.4Kbits requires at least a 5.1Kbps transmission rate in order to refresh the contents within the standard response time. Of course, faster response time is obviously preferable. Today, most terminals are operated at a maximum of 9.6Kbps.

- **Connecting Word Processors:** These are connected through the telephone lines using modems at up to 9.6Kbps. With these modems the standard size page (15.4Kbits) has a response time of about two seconds. Higher data rates decrease the response time. The most adequate response time is two pages per second.

- **Connecting Computers:** These require a transmission rate of millions of bits per second. When connecting computers that are located in different buildings, floors, offices, etc., but no more than several miles apart, a data rate of 1Mbps to 2Mbps is required. Higher transmission rates decrease the response time.

- **Electronic Mail:** It involves a terminal-computer communication, and everything discussed above is valid for E-mail. That means that a rate of 5.1Kbps to 9.6Kbps is required.

- **Facsimile Transmission:** It converts the scanned image into an electrical signal and transmits it over telephone or data lines. In this case, the transmission rate deals with the resolution, pixels by lines, (e.g. 256 pixels by 512 lines or 256 pixels by 256 lines) and not with characters per line per page. An adequate transmission rate of an image is that of 56Kbps. This rate can transmit a page in iess than a minute. Better resolution requires longer transmission time.

- **Voice Services:** These are concerned with the efficient switching and transmission of voice conversations. With the latest used method of PCM, all voice signals are converted in digital form. Their transmission requirements are 64Kbps and 32Kbps, respectively.

- **File Transfer:** is another basic application which is concerned with the transfer of files between intelligent devices, and a transfer rate of 1 to 10Mbps, is required.

The communication system must support the following data rates:

1. Terminal - Computer Connection : 5.1 to 9.6 Kbps
2. Computer - Computer Connection : 1.0 Mbps and above
3. Word Processor-Word Proc.Conn. : 9.6 Kbps and above
4. Electronic Mail : 5.1 to 9.6 Kbps
5. Facsimile : 56 Kbps and above
6. Voice : 32Kbps or 64Kbps
7. File Transfer : 1 to 10 Mbps

Transmission Requirements

c. Advanced Features Requirement

After the analysis of the user and transmission requirements, the major advanced features available in the telecommunication systems market should be examined in order to identify those that will help the target organization to increase productivity and reduce telecommunication costs. Among the most important features that the target organization has to consider are:

- **Automatic Call Distribution:** To distribute the work load (incoming calls) evenly over all of the employees in a group.
- **Back-up capabilities:** To eliminate redundancy problems.
- **Battery back-up:** To protect the system from electric power failures.
- **Direct Inward Dialing (DID):** To reduce personnel needed for attendant assistance.

- **Electronic or Digital Phones:** To provide employees with more capabilities.
- **Electronic mail:** For easy and rapid message manipulation of messages.
- **High Traffic Capacity:** To eliminate the blocking problem.
- **Intercom:** To provide easy and rapid connection among employees within the organization.
- **Least Cost Routing (LCR):** To reduce the long distance telephone cost.
- **Station Message Detail Recording:** To manage calls and reduce telephone abuse.
- **Voice mail:** To reduce the telephone tag problem.

The communication system must provide the following features:

1. Automatic Call Distribution (ACD)
2. Back-up Capabilities
3. Battery Back-up
4. Direct Inward Dialing (DID)
5. Electronic or Digital Phones
6. Electronic Mail
7. High Traffic Capacity
8. Intercom
9. Least Cost Routing (LCR)
10. Station Message Detail Recording (SMDR)
11. Voice Mail

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d. Additional General System Requirements

In addition to the above described requirements a number of other factors related to the system must be taken into consideration. These additional features are summarized below.

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1. The new telecommunication system must fit into the existing environment. Aspects such as common base cable plant and standard building wiring have to be considered.

2. All the communication circuits, computers, terminals, employees, and other elements must work in a cohesive fashion.

3. The system must minimize data transmission delays and downtime.

4. The system must be able to support new functions and data types that are expected to be added in the future, such as extension of local computing and word processing to other new departments.

5. The central telephone exchange must be relieved from data traffic.

6. All users must have access to a central link to PSTN, without the intervention of attendants.

7. The system must be capable of connecting homogeneous and heterogeneous devices, and operating with standard communication interfaces.

8. The system must provide voice and data integration for efficient facilities utilization, and common network planning and management.

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4. STEP FOUR: Possible Alternative Solutions

As the target organization's requirements are identified, the next step is evaluating the alternative systems. Actually, a system is required to accommodate information exchange among dissimilar user devices at dissimilar transmission rates. Its capacity and performance has to suit a rather large and changing user population.

Therefore, the selected system should be able to accommodate variable data rate input and output devices, and equipments from different vendors. High flexibility within this environment is mandatory so that users and their devices could be easily added, removed or relocated.

As communication patterns within the target environment are highly susceptible to change, these changes must be readily accommodated with a minimum impact on existing operations. The privacy, reliability and affordability of the telecommunication system must be high on the requirement list.

The most common of telecommunications technologies providing a multitude of new services and applications by combining telecommunications and computing are:

- Computerized Private Branch Exchange (CPBX).
- Local Area Network (LAN).
- Central Exchange (Centrex).

From the above three alternative solutions, the Centrex system will not be considered because the local central office mostly provides only analog services.

The remaining two alternatives will be evaluated in order to determine which is the most appropriate for the target organization. This evaluation will be based on the

target organization's requirements and on the trade-offs of each system in the following areas:

- Distance.
- Installation/Implementation.
- Voice/Data Integration.
- Reliability.
- Channel Capacity.
- Available Bandwidth.

a. Distance

Distance is an important consideration in a multibuilding environment. All target's stations operate within a maximum 2100 feet distance of each other. These distances are actual cable lengths that average about double the physical separation of stations.

(1) Computerized Private Branch Exchange

The CPBX allows digital transmission of voice and data between devices over distances of up to 3000 feet. Over the typical distances, which are less than 1000 feet for single building and less than 5000 feet for multibuilding sites, CPBXs can carry data at 1 Mbps. As for multibuilding sites, the distributed architecture of the CPBX allows switch modules to be located in each building which can be interconnected using broadband cable.

(2) Local Area Networks

Over the typical distances considered here, a broadband coaxial cable carry data at 500 Mbps. Although broadband trunks can run up to 30 miles, the usual length is less than five miles. The maximum usable length of a broadband system is determined by the number of amplifiers that can be connected in series without signal degradation. As amplifiers, taps and splitters are installed, additional signal attenuation is introduced. A baseband coaxial system, over the typical distances mentioned above, can carry data at up to 20 Mbps. For this system, communication is confined to a moderate sized geographical area, such as a single office building, a warehouse, or a campus. The distances typically supported by baseband systems is approximately 1500 feet.

(3) Conclusion

For intrabuilding situations, PBX and LAN approaches are about equal in the distances they can support. PBX is superior in multibuilding environment.

b. Installation/Implementation

About all existing office sites in Target corporation are wired with twisted pair for distribution of traditional telephone services.

(1) Computerized Private Branch Exchange

CPBXs are installed with at least two pairs of wires, only one of which is used for voice transmission. The second pair is installed for backup should the primary pair be damaged or to allow distribution of other devices. As such, most

CPBX installations have an available spare twisted pair for use with other approaches such as data PBXs.

(2) Local Area Networks

The LAN approach usually requires installation of new cable. In some buildings, broadband systems prove most cost-effective, while in others, where floor ducts are used, coaxial distribution may be prohibitive.

(3) Conclusion

The existing twisted pairs in buildings make any CPBX installation more readily feasible than LAN, for which a new coaxial cable is required. Broadband systems are characterized by high installation costs while baseband systems are characterized by implementation flexibility. Although, ring or bus topology requires less cabling than that of star topology used in CPBX systems.

c. Voice/Data Integration

Voice and data integration provides many advantages in terms of economy and efficiency. Data processing, word processing, electronic mail, facsimile, voice and data communication can be accomplished in an integrated business system to achieve organizational tasks in the most timely and economical method possible.

(1) Computerized Private Branch Exchange

CPBXs have evolved to effectively handle voice transmission and control. They also handle slow to medium (300-2.4Kbps) and medium to fast (4.8-

56Kbps) data transmission. The voice/data integration is designed into the CPBX system. Most CPBXs support simultaneous voice and data transmission.

(2) Local Area Networks

LAN systems have evolved to effectively handle data transmission. Broadband cable can handle voice, but at a high cost because additional tap and interface devices are required.

(3) Conclusion

CPBXs are superior to LANs, in providing voice and data integration capability.

d. Reliability

Reliability is concerned with the ability of the system to be used when and where required, providing consistently reliable service. Reliability gives a measure of the percentage of time that the system is operational. Its main factors are: availability, bit error, and maintainability.

(1) Computerized Private Branch Exchange

CPBXs are inherently a tree/star topology. As such, they provide a good degree of reliability in that stations, modules and station/module link components can fail without affecting higher level or parallel components. At the lowest distribution level the station failure of the wiring disables only a single instrument. The bit error rate is approximately 1 to 10^5.

(2) Local Area Networks

Shared-cable loops, rings, or buses may be partially or totally disrupted in the event of cable failure. The ratio of out of service terminals per failure is higher than with distributed CPBXs. At the lowest distribution level the station failure of the wiring disables only a single instrument in most cases. But ring systems and some types of bus devices failures can be disastrous. The bit error rate is approximately 1 to 10^{12}.

(3) Conclusion

Generally speaking, CPBXs are more reliable than LANs.

e. Channel Capacity

Channel capacity is concerned with the rate at which data can be transmitted over a channel.

(1) Computerized Private Branch Exchange

CPBX-based systems typically support data rates from 300bps to 9.6Kbps with 56Kbps technically possible but rarely used. They are best suited to devices with data rates of 300bps to 2.4Kbps with less than 10% utilization. Traffic is typically from communicating word processors, communicating copiers, microcomputers, interactive minicomputers, terminals, and printers.

(2) Local Area Networks

Baseband technology is enjoying a newfound popularity in networking minicomputers and microcomputers that exchange files and database

information. Time division schemes and ring or bus topologies are used to divide a single signaling channel to accommodate multiple users. Typically, baseband networks operate at 5 or 10Mbps and support up to 100 data devices. Broadband local networks typically support devices starting at 2.4Kbps with aggregate channel rates from 1 to 10Mbps. Generally, the shared-cable networks are designed to support transmission rates in the Mbps ranges. The cable sharing techniques, especially the TDM approach, allow this high bandwidth to be shared by devices with burst requirements.

(3) Conclusion

If transmission rates over 1Mbps are required for point-to-point communication, then the shared cable approach is clearly the winner over the CPBX. Most CPBXs will continue to be limited to 56Kbps traffic with the most currently installed office automation devices transmitting at less than 10Kbps.

f. Available Bandwidth

Available Bandwidth is a very important concept in communication because the capacity of a communication channel is partially dependent on its bandwidth. The greater the bandwidth, the greater the capacity. Digital signals require less bandwidth than analog.

(1) Computerized Private Branch Exchange

CPBXs employ digital representation of the human voice and the normal technique employed leads to one 4KHz voice channel being replaced by one 64Kbps bit stream.

(2) Local Area Networks

Baseband systems have a single serial digital channel operating at speeds of up to 10Mbps which has to be shared between all the stations on the cable. The maximum channel bandwidth is 50MHz. Broadband systems use traditional splitting techniques to obtain multiple connections on the same coaxial cable. Such systems represent the greatest bandwidth of the local communications technologies. Channel bandwidth is greater than 3KHz.

(3) Conclusion

Shared cable appears to have substantially higher bandwidth than CPBX since it operates in some implementations with a local basic capacity of 500Mbps.

g. General Conclusion

The comparison of Computerized Private Branch Exchange and Local Area Networks results in an overall CPBX superiority. The CPBX approach is superior in three of the six examined areas: reliability, installation/implementation and voice/data integration, while LAN approach is superior only in the channel capacity area. As for the distance and available bandwidth areas, the two approaches are about equal.

The above described superiority of CPBX to LAN systems is combined with some other factors:

- The target organization is not dealing with very large volumes of data.
- In some cases, there is no need for a LAN to be connected to the intercampus network. Simply by setting up a corporate shared network, departments can begin to merge their LANs into network interconnection to access information available elsewhere.

- Multiplexing and shared access are two methods that can be used to switch data through a CPBX.

It is becoming apparent that the target organization should proceed with the procurement of a Computerized Private Branch Exchange.

5. STEP FIVE: Request For Proposal (RFP)

After the evaluation of the target organization's requirements and the selection from alternative solutions the team has to prepare a document including as much detailed functional and performance specifications as possible. Technical requirements also have to be addressed, including such areas as: organization size, the number of lines, transmission facilities, security, future enhancements, etc. Finally, vendors should be required to provide proper maintenance to ensure a high level of system availability.

This document, which is referred to as a Request For Proposal (RFP), has to be issued to several vendors for bidding. The more accurate the RFP is, the better the vendors will address the system specifications.

V. CHOOSING A COMPUTERIZED PRIVATE BRANCH EXCHANGE

A. EVALUATING TELECOMMUNICATION SYSTEMS

The evaluation of a telecommunication system, where a number of alternatives exist that provide services of equal value, may be accomplished by comparing them directly against each other. Under such a condition, the objective is to select the alternative that provides the desired service (*technical performance*) at the least cost (*economic performance*).

As soon as alternatives are identified, evaluation criteria have to be established, analytical methods have to be identified, input data have to be collected, and finally the various alternatives have to be evaluated on an equivalent basis. The selection of the best system among several alternatives from different vendors involves the review of all systems' significant performance parameters from the standpoint of maximum or minimum requirement (degree of importance) and a number of evaluation criteria.

The evaluation criteria are dependent on the stated problem and the complexity of analysis. The most important criteria, related to the selection of a telecommunication system among several alternatives, is *cost-effectiveness*, which is based on the technical *effectiveness* and the *life-cycle cost* of the system.

B. COST-EFFECTIVENESS ANALYSIS

Cost-effectiveness is a measure of a system in terms of a system's effectiveness relative to its total life-cycle cost.

There are so many factors influencing the effectiveness and costs of a system that it is impossible to measure true cost-effectiveness. For this reason, specific cost-effectiveness *figures of merit (FOM)* are employed. These figures allow the comparison of alternative systems based on the relative merits of each one. The FOM examines specific parameters of a system such as: performance effectiveness, benefits, availability, supply effectiveness, etc., and compares them to a standard base: the life cycle cost.

System effectiveness is the ability of a system to perform its intended functions. System effectiveness involves a number of parameters such as: performance, operational availability, maintainability, size, weight, etc., that can be used to express system effectiveness in figure of merits.

Life Cycle Cost (LCC) is a systematic, analytical process of determining and listing the total cost of developing, producing, owning, operating, supporting and disposing of equipments or complete systems. The LCC is one of the most significant factors, for the evaluation of alternative systems, providing decision makers with significant economic information to determine the most cost-effective configuration of a system within budget limitations.

The Life-Cycle Cost includes the following four aggregate areas:

- Research and Development costs.
- Production and Investment costs.

- Operation and Support costs.
- Salvage costs.

Research and Development cost includes expenditures associated with the initial period of a project. Costs that can be considered as Research and Development costs are those for engineering design, market analysis, initial planning, software, and design documentation.

Investment cost includes expenditures involved in the purchase phase of a system and is concerned with recurring and nonrecurring costs. Examples of these costs are process development, facility construction, initial purchase of spare parts, etc.

Operation and Support cost includes expenditures occurring during the operational period of the system. Examples of these expenditures are: system service, maintenance activities, test and support equipment, technical data, facilities, and system modifications.

Salvage cost includes expenditures for system retirement, material recycling, nonrepairable items and spare parts, etc. Usually, it makes a positive cash flow at the end of a LCC analysis reflecting the system's salvage value.

These four aggregate cost areas can be further broken down into distinct *cost elements (CE).* To identify cost elements, inputs from both the customer and the vendor are necessary. Customer's inputs are concerned with such operational information as the number of voice and/or data terminals that will be on line, the number of tie trunks required, specific features, and the period time (hours) that the system will be used. Vendor's inputs are related to the system availability such as MTBF (Mean Time Between Failure), the maintenance cycle of the equipment, and the overhaul requirements

of the system. Estimates of these inputs is essential in identifying CEs to evaluate the actual cost.

The most important CEs are described below:

- ***Hardware Acquisition*** refers to the acquisition cost of primary use equipment, such as: data terminals, feature phones, system cabinets, integration equipment, etc.
- ***Maintenance Sets*** refers to the acquisition cost of maintenance sets. These sets are to be used for on-equipment item maintenance.
- ***Replacement Spares*** refers to the LCC of system replacement items.
- ***Spares Acquisition*** refers to the initial investment cost for spare parts, required to support the system.
- ***Support Equipment*** refers to the LCC of system support equipment purchased.
- ***Training*** refers to the expenditures needed for personnel training and includes the expenditures for training equipment.
- ***Technical Orders*** refers to expenditures for purchasing manuals, documentation, etc.
- ***Full Scale Development*** refers to the expenditures for developing primary use equipment, support equipment and associated software.
- ***System Integration*** refers to the expenditures to develop the integration hardware and software required to interface the system terminals to existing integrated systems.
- ***System Installation*** refers to the expenditures for installing the system, the terminals, cables, etc.
- ***Software Maintenance*** refers to the expenditures for software required to support the system functions.

C. EVALUATING VENDOR PROPOSALS FOR TARGET CORPORATION

The vendors that accept Target corporation's RFP have to prepare and submit a proposal within a predetermined time interval, usually eight to ten weeks. The selection team, as soon as receiving the proposals, has to start a detailed evaluation in order to select the vendor that will "do the job effectively at the lowest overall cost". To achieve that goal, a systematic process for evaluating the systems' characteristics and their economic performance must be followed:

1. STEP ONE: Preliminary Phase

Since it is not feasible to assess each vendor strictly on the basis of written proposals, the evaluation should be carried out in several phases. During a *preliminary phase*, vendors' proposals can be eliminated according to some basic attributes.

In this phase, target's selection team, can eliminate proposed systems that cannot handle voice and data in an integrated manner. In addition, vendors that have not had sufficient installations in the public or private sector and thus lack experience may also be eliminated.

2. STEP TWO: Decision Table

The next step, after the preliminary phase, is the construction of a *Decision Table* which will provide a means for, a technical evaluation of the remaining proposals on the most objective possible basis. Since each system enumerates hundreds of features, the selection team's goal is to create a Decision Table containing the most desirable

features for the target organization. With respect to these features, the degree of conformity of each proposal will be measured.

Suppose that the result from the preliminary evaluation is a short list of five vendors. Then each proposal can be listed along with their systems characteristics and features in a Decision Table like the one which is presented in Table I. In each column of the table a candidate system is listed. Candidates systems are represented letters, "A" through "E", instead of the name and the proposed model of each vendor. In the leftmost column, the features and characteristics that are considered very important for the target organization have been listed.

Described below is the meaning of each item listed in the leftmost column. What is desired by the target organization for each item is indicated in brackets underlined:

1. First Installation indicates the year the vendor first installed this system. This entry helps the age of the design and the experience of the vendor. Of course, the current available systems in the market are quite different from those first installed. Since as the provided features and capabilities change continuously. (Vendor with as much as high experience and new age design).

2. Type of Station indicates the type of communication devices that can be supported by the system. These may be analog, digital, hybrid, or even a combination of two or all of them. (Analog and Digital).

3. Voice/Data/Both indicates the capability of the system to handle voice only, data only, or both. (Both).

4. Number of Voice Stations indicates the maximum number of stations with voice capability that can be supported by the system. (Up to 1000).

5. Number of Twisted Pairs indicates the number of copper wires (pairs) required to support voice, data, or intercom. (Two pairs).

Table I Decision Table

ALTERNATIVE/ ATTRIBUTES	SYSTEM "A"	SYSTEM "B"	SYSTEM "C"	SYSTEM "D"	SYSTEM "E"
1ST INSTALLAT.	1982	1982	1982	1976	1983
TYPE OF STATION	DIGITAL	DIGIT./ANAL.	HYBRID	DIG./ANAL./HYBR.	DIGIT./ANAL.
VOICE/DATA/BOTH	BOTH	BOTH	BOTH	BOTH	BOTH
# VOICE STATION	10K	12K	768	5K	992
# TWISTED PAIR	4	1	2	1 or 3	2
# OF PORTS	10K	12K	768	8K	992
# OF DATA PORTS	10K	12K	400	2K	864
# OF CONSOLES	40	30	24	63	12
DATA RATE SYN.	56	56	56	56	56
DATA RATE ASYN.	19.2	19.2	19.2	19.2	19.2
REDUNDANCY	NO	YES	YES	YES	YES
BATTERY BACK-UP	YES	YES	NO	YES	YES
LEAST COST ROUT	YES	YES	NO	NO	YES
DIR.INWARD DIAL	YES	YES	YES	NO	YES
VOICE MAIL	YES	YES	YES	YES	YES
EXPANDABILITY	YES	NO	YES	YES	YES
NON-BLOCKING	ES	YES	YES	YES	YES
X.25 INTERFACE	YES	YES	NO	NO	NO
T-1 INTERFACE	YES	YES	NO	NO	YES
SECURITY	YES	NO	NO	YES	NO
PROTOCOL CONV.	NO	YES	YES	NO	NO
INTERCOM	YES	YES	YES	YES	YES
MESSAG. RECORD.	YES	OPTIONAL	YES	YES	YES
PRICE/LINE ($)	1000	600-1000	400-600	550-1000	400-1000

6. **Number of Ports** indicates the number of locations on the system that provide an interface between the system and lines and/or trunks (Up to a few hundred).

7. **Number of Data Ports** indicates the number of ports that provide an interface between the system and data terminals. (Up to a few hundred).

8. **Number of Attendant Consoles** indicates the number of attendant consoles from which an attendant can monitor and supervise the general operation of voice communications within the system. (Up to 20).

9. **Data Rate Synchronous** indicates the maximum data rate of synchronous transmission. (56Kbps).

10. **Data Rate Asynchronous** indicates the maximum rate of asynchronous data transmission that can be handled by the system. Example of asynchronous data are the characters that are typed from a keyboard. (19.2Kbps).

11. **Redundancy** indicates the availability of back-up processors which can be switched in when the on line processor fails. (YES).

12. **Battery Back-up** indicates whether battery back-up is available providing for an uninterruptable power supply or uninterruptable memory only operation. (YES).

13. **Least Cost Routing (LCR)** indicates the availability of LCR feature as an integral part of the system. (YES)

14. **Direct Inward Dialing (DID)** indicates the availability of DID as an integral part of the system. (YES).

15. **Voice Mail (VM)** indicates the availability of VM as an integral part of the6 system. (YES).

16. **Expandability** indicates the capability of the system for easy growth in software and hardware components. (YES).

17. **Non-Blocking** indicates the availability of non-blocking features which allow all users to reach a port without any blocking or limitation. (YES).

18. **X.25 Interface** indicates the availability of packet interface software and hardware enabling the system to be directly connected with data terminal equipment. (YES).

19. T-1 Interface indicates the availability of interface cards so that T-1[6] carrier can be directly interfaced with the system. (YES).

20. Security indicates the availability of security functions that render the system fault-tolerant. (YES).

21. Protocol Conversion indicates the availability of the Protocol Conversion feature that connects dissimilar format and relative timing of message exchange (protocol) between communicating systems, such as: word processors, terminals, etc. (YES).

22. Intercom indicates the availability of the Intercom feature which allows multiappearance voice-terminal users to gain rapid access to other multiappearance voice-terminal users in the same intercom group. (YES).

23. Message Detail Recording indicates the availability of the MDR feature which logs each outgoing long distance call, or even internal calls, for communications traffic analysis and in-plant billing for communications services purposes. (YES).

24. Price Per Line indicates the cost, in U.S. dollars ($), of each line that has to be connected with the system. (The lowest possible).

3. STEP THREE: Technical Evaluation

With a simple observation of entries[7], some systems may be found clearly falling behind others. However, it is not the case. For example, system "C" does not provide Battery back-up, Security, X.25 Interface, and the number of provided voice stations (768) is less than the required by the corporation (1000). These disadvantages have to be compared with some advantages that the system provides, such as low price/line, vendor's experience and hybrid type stations that render system "C" superior to other alternatives.

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[6]Is a standard used by carrier digital transmission systems. It includes 24 voice frequency channels at 64Kbps each with framing and signaling, i.e., a total of 1544Mbps.

[7]The entries in Table 3 are representative of actual systems that are available in the market.

In such a situation, techniques that are used in a multicriterion decision making is needed. One of the most commonly used techniques is a process known as a *weighting process.*

During the weighting process, each vendor's attributes have to be scored on the basis of low (1 to 3), medium (4 to 6), or high (7 to 10). The scoring has to be carried out by each team member voting for each attribute in the Decision Table. Weights are assigned by averaging the weight factor recommendations of each team member. The result of such a process is a new table as the one represented in Table II. High score (7-10) indicates that the entry meet more than the corporation's minimum requirements; medium score (4-6) indicates that the entry meet the minimum requirements; and finally, low score (1-3) indicates that the entry does not meet the minimum requirements. In Table 4, the score (weight) is just an indication of the importance of each vendor's features and characteristics, for the target corporation.

Next the scores for all the listed features must be averaged using some weights to come up with an overall score for each alternative. What weight to assign to each feature is a matter of judjment. The simplest weighting method is to give a uniform weight to every feature.

The selection team can proceed to the elimination of some more vendors that will receive low weighted average score. While the weighting process plays an important role in the decision-making process, financial factors have also to be considered.

4. STEP FOUR: Life Cycle Cost (LCC) Analysis

Suppose that, from the weighting process, two more systems are eliminated. The remained systems have to be evaluated according to their Life Cycle Cost. The systems assumed to be eliminated are the "A" and "C". The first one is eliminated not withstanding its very high because it would be because it would br excessive for the target corporation to procure a system with capabilities that will never be used. The second one is eliminated because of its low capabilities that cannot meet the minimum requirements effectively.

The remaining three alternatives are subjected to a detailed analysis of costs be incurred over their lifetime, which is the Life Cycle Cost (LCC) analysis.

The purpose of LCC analysis is to determine if the system finally selected is an economically acceptable solution when budget limitations exist. In this sense, it is an effort to evaluate a total system cost figure, which in turn can be used to assist the selection team in realizing the magnitude of the investment required for the procurement.

Any cost for one alternative that is absent in whole or in part for another alternative can be identified by the following steps:

- Collection of all the costs associated with each alternative being considered.
- Elimination of those costs that do not differ between alternatives.
- Elimination of those costs that have already been incurred (sunk costs) and cannot be changed by any current or future decision (e.g., the salary of the external consultant who may be hired to help in the study of the corporation's telecommunication system).

- Decision making based on the remaining costs of each system. The present worth of those costs has to be evaluated in order to identify the system with the highest *Net Present Value (NPV).*

Table II Decision Table after the weighting process

ALTERNAT./ ATTRIBUTES	"A"	SCORE	"B"	SCORE	"C"	SCORE	"D"	SCORE	"E"	SCORE
1ST INSTAL.	1982	6	1982	6	1982	6	1976	7	1983	5
STATION TYP	DIGIT	4	DG/AN	6	HYBR.	8	D/A/H	10	DG/AN	6
VC/DAT/BOTH	BOTH	6	BOTH	6	BOTH	6	BOTH	6	BOTH	6
# VC STAT.	10K	9	12K	10	768	3	5K	8	992	6
# TWIST. PR	4	8	1	5	2	6	1/3	7	2	2
# OF PORTS	10K	9	12K	10	768	3	8K	8	992	6
# DATA PORT	10K	9	12K	10	400	4	2K	8	864	6
# TIE TRUNK	2K	10	90	6	384	8	1K	9	255	7
# CONSOLES	40	9	30	8	24	7	63	10	12	6
D.R. ASYNCHR	19.2	6	19.2	6	19.2	6	19.2	6	19.2	6
D.R. SYNCHR.	56	6	56	6	56	6	56	6	56	6
REDUNDANCY	NO	2	YES	6	YES	6	YES	6	YES	6
BAT.BACK-UP	YES	6	YES	6	NO	3	YES	6	YES	6
D.I.D.	YES	6	YES	6	YES	6	NO	3	YES	6
VOICE MAIL	YES	6	YES	6	YES	6	YES	6	YES	6
EXPANDABILIT	YES	6	NO	3	YES	6	YES	6	YES	6
NON-BLOCKING	YES	6	YES	6	YES	6	YES	6	YES	6
X.25 INTERF.	YES	6	YES	6	NO	3	NO	3	NO	3
T-1 INTERFAC	YES	6	YES	6	NO	2	NO	3	YES	6
SECURITY	YES	6	NO	6	NO	3	YES	6	NO	3
PROT. CONVERS	NO	3	YES	6	YES	6	NO	3	NO	3
INTERCOM	YES	6	YES	6	YES	6	YES	6	YES	6
MES. RECORD.	YES	6	OPT.	3	YES	6	YES	6	YES	6
PRICE/LINE	1000	10	600-1000	9	400-600	6	550-1000	8	400-1000	7

Net Present Value is the most significant LCC indicator. It is the difference between the Present Value (PV) of all cash inflows and the present value of all outflows that are associated with an investment project. NPV determines the relative cost of the remaining alternatives. Cash flows express the CEs that mentioned above.

In using the NPV analysis many factors and CEs have to be considered, such as:

- **Initial Investment** is concerned with the initial investments made when a system is acquired. It includes amounts paid for material and apparatus, installation labor, engineering labor, software, initial purchased spare parts,etc.
- **Operating Cost** represents expenditures needed to operate the system, usually of a recurring nature. Such expenditures are dependent upon the number and kind of operating units, where the system is located, air conditioning units in use, etc.
- **Maintenance Cost** include expenditures for overhauling the system after some years of life.
- **Salvage Cost** is the amount of cash inflows that are occurred when the system is disposed of at the end of the life being studied.
- **Cash Inflows from Using the System** are cash inflows that are incurred by using the specific system. As for example, cash inflows from the release of employees, controlable communication bills, etc.
- **The Rate of Return** the discount rate chosen to discount cash flows to PV. Usually, a discount rate of 16 to 20% is used for a before-tax cost of capital and a rate of 8 to 10% is used for an after-tax figure.
- **Income Taxes** the change in the amount of income subject to several kinds of taxes.
- **Life of System** most important factor because all the above calculations are based on the period that the system is expected to be used.
- **Costs:** the costs that are present under all the alternatives, such as: labor costs ($/hour), power costs ($/KWh), floor space ($/ft^2 year), etc.

Assuming that the remaining alternatives have the economic characteristics that are shown in Table III, an NPV analysis can be applied and the more economic system can be identified. All of the costs that are presented on Table III are either given by the vendors, or are computed by the users using various cost estimation techniques and computer aids.

Table III. Economic Characteristics of Alternative Systems

COSTS	SYSTEM"B"	SYSTEM"D"	SYSTEM"E"
Initial Investment:	$145,000	$137,000	$173,000
Operating Costs :	$ 57,000	$ 74,000	$ 69,000
Maintenance Cost :	$ 5,000	$ 3,000	$ 4,000
Salvage Costs :	$ 14,500	$ 13,700	$ 17,300
Cash Inflows :	$ 35,000	$ 40,000	$ 47,000
Common Costs :	$ 27,000	$ 27,000	$ 27,000

The NPV of each system may be computed using the above inflow and outflow values, and assuming a discount rate of 20%, and a five years period life for the system. Table VI shows the computation of the NPV of each of the remaining systems. The system with the least negative highest NPV, i.e., system "D" (-$87,590), is the most effective system.

The NPV of each system is the algebraic sum of all discounted cash flows less the cost of the initial investment. The numbers in brackets are cash outflows, i.e., negative numbers, and the rest are cash inflows, i.e., positive numbers.

Table IV Net Present Value Method

COST ELEMENT	YEARS WITH CASH FLOWS	AMOUNT OF CASH FLOWS	DISCOUNT RATE (20%)	PRESENT VALUE
SYSTEM "B"				
Initial invest.	Now	$(145,000)	1.000	$(145,000)
Operating costs.	Now	$(57,000)	1.000	$(57,000)
Maintenance cost.	4	$(5,000)	0.482	$(2,410)
Salvage cost..	5	$ 1,450	0.402	$ 583
Cash inflows..	1-5	$ 35,000	2.991	$ 104,685
NET PRESENT VALUE..				$(99,142)
SYSTEM "D"				
Initial invest..	Now	$(137,000)	1.000	$(137,000)
Operating costs.	Now	$(74,000)	1.000	$(74,000)
Maintenance cost	3	$(3,000)	0.579	$(1,737)
Salvage cost....	5	$ 13,700	0.402	$ 5,507
Cash inflows....	1-5	$ 40,000	2.991	$ 119,640
NET PRESENT VALUE..				$(87,590)
SYSTEM "E"				
Initial invest.	Now	$(173,000)	1.000	$(173,000)
Operating costs.	Now	$(69,000)	1.000	$(69,000)
Maintenance cost	4	$(4,000)	0.482	$(1,928)
Salvage cost...	5	$ 17,300	0.402	$ 6,955
Cash inflows...	1-5	$ 47,000	2.991	$ 140,577
NET PRESENT VALUE..				$(96,396)

The discounted cash flows can be calculated for each period in two ways:

- By using the formula:

$$P = \frac{Fn}{(1+r)^n}$$

Where: **P** is the Present Value, $\mathbf{F_n}$ is the amount to be received in **n** years, and **r** is the rate of interest.

- Or, by using Tables containing the Present Value of $1 to be received each year over a series of years at various interest rates.

Finally, in these calculations the income taxes have not been considered. To calculate the tax effects, a tax factor needs to be calculated for each type of outflow or inflow, depending on the tax implication of that flow. If tax effects are considered, the discount rate should be changed from 20%, to 8 or 10%.

5. STEP FIVE: Final System Evaluation

During this phase, the selection team has to summarize all the features and CEs that entered into the system evaluation. Factors that entered in the evaluation, such as desirable features, vendors' experience, LCC, etc., will have to be weigthed for their relative importance, and a decision has to be made about the primary system and vendor. After that, the primary vendor has to be notified.

The method of weghting process that described above is not the perfect one. There is a degree of subjectivity in the relative weights and in the individual ratings of the vendors on the various points. However, it provides a means through which a company can attempt to be as objective as possible and reduce subjectivity to a minimum. At least, it is a decision process for which the reasons for specific selections being made can be rationalized.

CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

In this study, an attempt was made to show how a medium-sized organization can transform its poor information environment into a progressive and self-reliant telecommunication utility. That is, it shows how the organization's old telecommunication system can be upgraded to a reliable and cost-effective telecommunication system, in order to accommodate its growing needs. A case of a specific organization has been studied to demonstrate the transition towards new telecommunication systems.

The plan for telecommunication support involves the following steps:

1. Take into consideration the relevant factors.

- Organization's current telecommunication system.
- Organization's future needs and devices that will be purchased.
- Current available technology in telecommunications.
- The already existing features and hardware that can continue to be used.
- Major advanced features that can reduce the telecommunication costs and increase productivity of the company.

2. Identify the organization's problems.

- Inability of existing telecommunication system to meet organization's rapid growth.
- Blockages during peak times.
- Transmission errors and circuit outages.

- Significant problems associated with capacity, cost, and rate of expansion, concerning the primary data communication system.
- Outdated hardware equipment.
- Unavailability of important features.

3. Propose possible alternative solutions.

- Computerized Private Branch Exchange (CPBX).
- Local Area Network (LAN).
- Central Exchange (CENTREX).

4. Evaluate alternative solutions on the following areas:

- Distance.
- Installation/Implementation.
- Voice/Data Integration.
- Reliability.
- Channel Capacity.
- Available Bandwidth.

In the case of the organization considered in this thesis, the most desirable alternative turned out to be the *computerized private branch exchange (CPBX)*. Implementation involves evaluating vendor's proposals both technically and economically.

The *computerized private branch exchange (CPBX)* was selected as the most appropriate telecommunication system for this organization, since CPBXs have the communications capability for both voice and data. The CPBXs and the twisted-pair wiring associated with it can serve to link any kind of data devices found in the

organization. Whether it is more effective and economical than a coaxial cable-based local area network depends on whether the user needs to exceed the 56Kbps limit. Transmissions up to 56 Kbps are adequate to handle facsimile transmissions.

In terminal-to-computer communications, where the requirements are low bandwidth and minimal delays, the CPBX can support a large number of devices, produces little delay, and is quite competitive with the alternative of coaxial-based systems.

There is also a role for the CPBXs in handling the traffic from personal computers, intelligent terminals, and word processing systems.

Generally, the incremental cost at which a CPBX can meet its communication needs will be determined by the organization's requirements.

B. RECOMMENDATIONS FOR FUTURE RESEARCH

Based on the overall analysis presented in this study, the following areas are recommended for further research:

- The *Computerized Private Branch Exchange* as a private communication system in a Naval base, available across the Navy, ship and shore alike.
- Technical and economic evaluation of a Computerized Private Branch Exchange using optical fiber to support high-speed graphics terminals.

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